104

S. HRG. 104–242

NASA MISSION TO PLANET EARTH PROGRAM

Y 4. C 73/7: S. HRG. 104-242

ASA Mission to Plant Earth Program...

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

JUNE 13, 1995

Printed for the use of the Committee on Commerce, Science, and Transportation

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ISBN 0-16-052050-9

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HEARING ON THE NASA MISSION TO PLANET EARTH PROGRAM

TUESDAY, JUNE 13, 1995

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The committee met, pursuant to notice, at 9:57 a.m., in room SR–253, Russell Senate Office Building, Hon. Conrad Burns (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Louis C. Whitsett, staff counsel, and Timothy B. Kyger, professional staff member; and Patrick H. Windham, minority senior professional staff.

OPENING STATEMENT OF SENATOR BURNS

Senator BURNS. This hearing will come to order.

Today the subcommittee will examine NASA's Mission to Planet Earth program. Mission to Planet Earth is NASA's $8 billion satellite program aimed at studying how the oceans, land, and atmosphere work as a system in order to understand and predict global climate change.

For those of us representing farm states, weather and water are our livelihood. Mission to Planet Earth promises dramatic improvements in our ability to predict climate change and manage our scarce water resources.

If those expectations are met, the program will easily pay for itself in lives and property saved, and improved water management throughout this country and throughout the world.

But nobody has to tell us, because it is in every newspaper every day that, yes, we are in tough budget times. NASA is planning to cut $5 billion over the next 5 years and the Senate and House budget plans call for even deeper budget reductions.

While we all applaud NASA efforts to cut costs through work force reductions and consolidating activities, the reality is that NASA will eventually be forced to cut some programs.

In that connection, we will have to make some hard decisions with regard to many equally deserving programs at NASA. In making those decisions, one of the most important criteria must be the program's relevance to the taxpayer.

In other words, how does a particular program enhance the life of the average taxpayer? Against that standard, Mission to Planet Earth fares, in my opinion, very well.

In the past, Mission to Planet Earth seemed to suffer from an overemphasis on global warming and often became a collateral vic-

tim of the controversy surrounding that issue. Mission to Planet Earth, however, is much broader than global warming.

Mission to Planet Earth will tell us about ozone depletion which poses a particular health risk to those folks who have to work in the sun, and, of course, that will be my farmers and rangers, as well as their crops and their livestock.

Mission to Planet Earth will help us unlock the secrets of El Niño, the ocean current phenomenon that causes floods and droughts every three to 5 years, for some reason or other.

The main strength of the Mission to Planet Earth lies in the practical applications of its satellite data. That data will enable farmers, foresters, and many other folks to analyze hundreds of thousands of acres for soil condition, water content, disease, and vegetation classification, without ever having to leave their house or office.

They will permit mappers to develop sophisticated color 3–D imagery for the use by a broad range of customers. Today, the subcommittee will hear from several witnesses who will discuss how they are using remote sensing imagery and what future applications are expected to emerge from Mission to Planet Earth.

While Mission to Planet Earth is a worthwhile program, it does have its critics. The subcommittee is aware of the opposition of several members in the other Chamber.

The opponents say that the Mission to Planet Earth is bad science. They also claim that billions can be saved in the program through reducing its data management system, employing microminiature satellite technology, and flying some instruments on commercial satellites.

These criticisms have raised some legitimate issues about the merits of the program. So this hearing will provide NASA and other supporters of the program an opportunity to address those issues directly and, we would hope, candidly.

So let me introduce the panel that we will be hearing from today, Dr. Charles Kennel, who is the Associate Administrator, Mission to Planet Earth Program, for NASA; Dr. Paul Smith—let me have you all come forward, if you would—Dr. Paul Smith, Director, Institute of Atmospheric Sciences, of South Dakota School of Mines and Technology, from Rapid City, South Dakota; Mr. Richard Bowers, City Manager, city of Scottsdale, Arizona.

We do not want any golf courses bellying up down there. I had to throw that in there. [Laughter.]

Senator BURNS. We also have Mr. Al Watkins, Director, National Mapping Division, United States Geological Survey; and Mr. Tommy Thompson, Resource Manager, for Louisiana——Pacific Corporation, from Calpella, California.

If you gentlemen would come up. Do we have enough chairs for you? Maybe we should have put them in two different panels, but I do not think so.

I will call on Dr. Charles Kennel first for his testimony. We thank you for coming this morning.

[Prepared statement of Senator Burns follows:]

PREPARED STATEMENT OF SENATOR BURNS

This hearing will now come to order. Today the Subcommittee will examine NASA's Mission to Planet Earth program. Mission to Planet Earth is NASA's $8-billion satellite program aimed at studying how the oceans, land, and atmosphere work as a system in order to understand and predict global climate change. For those of us representing farm states, weather and water are our lifeblood. Mission to Planet Earth promises dramatic improvements in our ability to predict climate change and manage our scarce water resources. If those expectations are met, the program will easily pay for itself in lives and property saved and improved water management.

We are in tough budget times. NASA is planning to cut $5 billion in five years and the Senate and House budget plans call for even deeper budget reductions. While we all applaud NASA efforts to cut costs through workforce reductions and consolidating activities, the reality is that NASA will eventually be forced to cut some programs. In that connection, we will have to make some hard decisions with regard to many equally deserving programs at NASA. In making those decisions, one of the most important criteria must be the program's relevance to the taxpayer. In other words, how does a particular program enhance the life of the average taxpayer? Against that standard, Mission to Planet Earth fares very well.

In the past, Mission to Planet Earth seemed to suffer from an overemphasis on global warming and often became a collateral victim of the controversy surrounding that issue. Mission to Planet Earth, however, is much broader than global warming. Mission to Planet Earth will tell us about ozone depletion which poses a particular health risk to our farmers and ranchers, who work outdoors, as well as their crops and livestock. Mission to Planet Earth will help us unlock the secrets of El Niño, the ocean current phenomenon that causes floods and droughts every three to five years.

The main strength of Mission to Planet Earth lies in the practical applications of its satellite data. That data will enable farmers and foresters to analyze hundreds of thousands of acres for soil condition, water content, disease, and vegetation classification without ever having to leave their house or office. They will permit mappers to develop sophisticated color 3-D imagery for use by a broad range of customers. Today, the Subcommittee will hear from several witnesses who will discuss how they are using remote sensing imagery and what future applications are expected to emerge from Mission to Planet Earth.

While Mission to Planet Earth is a worthwhile program, it does have its critics. The Subcommittee is aware of the opposition of several members in the other Chamber. The opponents say that Mission to Planet Earth is bad science. They also claim that billions can be saved in the program through reducing its data management system, employing micro-miniature satellite technology, and flying some instruments on commercial satellites. These criticisms have raised some legitimate issues about the merits of the program. This hearing will provide NASA and other supporters of the program an opportunity to address those issues directly and candidly.

Let me welcome our distinguished panel of witnesses here with us this morning. We look forward to hearing your testimony on the Mission to Planet Earth program.

STATEMENT OF SENATOR HOLLINGS

PREPARED STATEMENT OF SENATOR HOLLINGS

In 1989 and 1990, I authored the Global Change Research Act, a bipartisan statute to establish a legislative framework for the then-new interagency Global Change Research Program. That program had begun under the Reagan and Bush Administrations, with strong support from many in Congress. Its purpose was, and remains, to take advantage of new satellite technology and new scientific insights to improve our understanding of seasonal weather changes, longer-term climate changes, and the effect of human actions on the planet's environment.

The research begun in the late 1980s is beginning to pay off. Today, for example, we have much better advanced warning of periodic El Niño effects in the central Pacific—changes in Pacific temperature patterns which in turn have dramatic effects on Pacific fisheries, lead to increased rainfall and floods along the West Coast and in the Midwest, and affect North American agriculture.

Mission to Planet Earth is the contribution of the National Aeronautics and Space Administration (NASA) to the Global Change Research Program. The satellites NASA launches will provide an unprecedented view of our planet and its climate. And the data those satellites provide, along with data from the Commerce Department's weather satellites and other sources, will give scientists and natural resources agencies invaluable information.

I am pleased that the Science Subcommittee is holding this morning's hearing on this important program, and I look forward to reviewing the testimony.

STATEMENT OF CHARLES KENNEL, ASSOCIATE ADMINISTRATOR, MISSION TO PLANET EARTH, NASA, ACCOMPANIED BY: ROBERT HARRIS, DIRECTOR, SCIENCE DIVISION, NASA; DR. DIXON BUTLER, DIRECTOR, DIVISION OF DATA AND INFORMATION SYSTEMS

Dr. KENNEL. Thank you very much, Mr. Chairman.

It is a pleasure to be here to speak on behalf of Mission to Planet Earth. Before I start, I would like to introduce two of those dedicated NASA colleagues that you mentioned earlier, Dr. Robert Harris, beside me, is the director of our science division, and in the back is Dr. Dixon Butler, who is the director of our division of data and information systems.

Also, I have provided for the benefit of the committee a number of documents which I would like to have read into the record, if that is possible.

You will find a formal written statement, a summary of some of the more interesting applications of Landsat data, that I am sure will be of interest to this committee, and finally, a book of general information about the whole Mission to Planet Earth program.

This has the kind of things that your staff and constituents might want and need to know in a hurry. In that regard, NASA does have an information office set up ready to answer questions from members of your staff on short notice.

So with that, I would like just briefly to begin.

PREPARED STATEMENT OF DR. CHARLES KENNEL

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss NASA's efforts to better understand planet Earth and to provide you with a sense of how the program will generate solid science results and benefits to all Americans—both today and in the future. Mission to Planet Earth is one of the most important efforts underway in NASA today and is a critical part of the global effort to unlock the secrets of the environment.

A New Perspective on the Earth

When the astronauts first looked back on the Earth during their trip to the Moon, they saw a small, blue "marble" framed against a sea of dark, empty space. That picture changed the way we think about the Earth. NASA's missions to other planets have found them to be fascinating and diverse, but lifeless and sterile. We know of no place like the Earth.

What the astronauts observed was a planet in a constant state of change. We understand some of these changes pretty well—short term weather forecasts, hurricane tracking, and the way things grow. But we are missing a lot of other critical information, like the kind of data we need to predict how the climate will shift a year from now, and what the effects will be on people whose livelihoods depend on that climate—farmers, water managers, fishermen.

As we have come to recognize the economic, social, and scientific need to better understand how the Earth works, the U.S. has become a leader in organizing the global effort to observe the global environment and its effects on human quality of life. NASA has developed a program—Mission to Planet Earth—that captures our spirit of exploration and focuses it back on the Earth. Building on our observations of the Earth since the dawn of the space program—among other things, we built the first weather satellites—NASA is using its unique capabilities to bring congruency to a disconnected series of individual observations and to provide a global perspective of our land, air, water, and life. Mission to Planet Earth is an essential part of the U.S. Global Change Research Program—a national program consisting of many federal agencies which is committed to studying climate change on a global scale.

Mission to Planet Earth has been challenged to answer the timely questions about our planet that have been raised to a high level of consciousness in recent years. As we begin to form and validate viable theories about the Earth, NASA has answered the call to provide a service no other agency can offer: cutting-edge observations from space. Instead of being captive to whatever climate changes may occur over time, NASA and its interagency and international partners are striving to discover patterns in climate that will allow us to predict and perhaps respond to environmental events—such as floods and severe winters—well in advance of their occurrence. Nations, regions, and individuals can then use this knowledge to prepare for these events, likely saving countless lives and resources.

We need to begin these valuable measurements now. For example, these observations and analyses will lead to the development of long term weather prediction, which will greatly improve both our daily lives and longer term planning. Farmers can begin to better manage what has been the greatest risk factor in their business: the uncertainty of climate patterns. Losses of crops and livestock previously caused by shifts in seasonal weather patterns or by adverse weather conditions could be reduced by altering crop/livestock selection, exploring innovative farming techniques, or perhaps not planting certain crops during a particular season. Market forces might allow farmers in regions not under threat to increase their productive capabilities to prevent shortages.

Uncertainty affects the nations of the world in different ways. African nations are often concerned with severe droughts while those in Southeast Asia may desire to know with more precision when a monsoon may hit their shores. The U.S. is concerned with the likelihood of floods along the Mississippi, rainfall patterns over agricultural areas, and damaging storms along our heavily populated coastlines. Since the entire Earth is affected by climate changes, Mission to Planet Earth is an international program which will enable regional forecasts to identify potential trouble spots around the globe in the future.

Science is the foundation of Mission to Planet Earth

While the beneficiaries of Mission to Planet Earth are many and range from farmers to the insurance industry, the program is grounded in solid science. Advanced scientific endeavors are not new to NASA: we were pioneers in developing the weather, communications, and land-sensing satellites that produce data and images which are now a part of our daily lives. We learned that we must have good science before these practical benefits are possible.

NASA's Mission to Planet Earth program is designed to address a fundamental scientific challenge: how do the Earth's land, water, air, and life all interact to produce the environment in which we live? Scientists believe that understanding how each of these parts of the Earth are linked to each other is the key that will help provide the "user's guide" for our planet. The potential human benefits of this understanding are broad and substantial.

To do this complex job, one must go beyond the traditional approach to studying the Earth (i.e., looking at each individual part) and establish one that focused on the "big picture." NASA's program expands the conventional, departmentalized scientific approach to encompass the Earth as a unified system: interdisciplinary scientists from Maine to Hawaii and from the High Plains to Texas—and from the US to more than a dozen other nations—are joined together through a unique information system to explore the complex interrelationships of Earth's land, air, water, and life. Though ground and aircraft measurements certainly play an important role for these pioneering scientists, only space can provide the economical means for providing these observations on a global scale.

The scientific community spelled out the critical pieces of the puzzle that we need to have in order to gain the understanding we seek. They laid out the most fundamental questions which need to be answered and described the observations needed to answer them. Over the course of the last three Administrations, NASA and its partners in the U.S. Government and around the world responded to this challenge by developing complementary and interconnected observation, data, and research systems designed to provide the most cost-effective means of acquiring and analyzing the highest-priority measurements. The resulting science will provide U.S. leadership in the development of an international consensus on the state of the Earth today and in the future. We are confident that we have developed a balanced approach that will yield not only long term predictions of climate change, but will also provide short term information which will benefit states and localities, educational institutions, the business community, and the public at large.

A Science-Driven Program

The primary method for making these important measurements are space-borne satellites: they provide the global perspective and precision we must have to discern the intricate interactions of our land, air, water, and life. How much carbon dioxide seeps down into the ocean? How does the movement of warm water in the Pacific influence flooding along the Mississippi River? How do increases in human population affect our climate? Though some of these questions may seem esoteric, the answers to many of them will be the foundation from which practical benefits will flow.

The perspective from space is critical. Only from above can we observe places where it is impossible (or very difficult) to make ground observations—like distant parts of the world's oceans, deserts, and polar regions. Space observations enable us to measure the globe on a regular basis and to do so far more cost effectively than would be possible from the ground. Using this "big picture," scientists can then build computer models that simulate how the Earth behaves. More importantly, they can use this global understanding to focus on what people really care about: what is happening in their state or region. In essence, the global nature of the science in Mission to Planet Earth is actually what will enable most of the practical benefits closer to home.

A quick example of the need for global observations is El Niño. Occurring on a fairly regular basis for hundreds of years, El Niño is a climate disturbance caused by the eastward movement of warm water across the Pacific. When the water reaches the coast of the Americas, it totally jumbles the climate patterns in North and South America. This year's heavy rains in California and the 1993 Mississippi floods are thought by many scientists to be among examples of the El Niño's effect. As far away as Austrailia and Africa, the same El Niño effect can cause drought. Only with global measurements from space can scientists track and begin to predict the movement of the El Niño and monitor its many effects. As measurements improve over the coming years, researchers will be able to predict these events—and their consequences—more than a year in advance, giving farmers, landowners, and others a chance to plan accordingly and perhaps avoid devastating losses. We could make advance preparation for floods, advise farmers to customize their crops for the anticipated weather patterns, and encourage property owners to avoid building in particular regions. If a region is projected to be abnormally cold and wet, utility companies could plan to have excess capacity and local governments could prepare for excessive snowfall.

The uncertainty of our climate patterns is one of the many unanswered questions about the Earth; NASA has already begun to answer some of them. NASA launched the UARS satellite to study the atmosphere and joined with the Russians on TOMS METEOR to explore ozone depletion. More recently NASA collaborated with France to send the TOPEX/Poseidon spacecraft into orbit, which will precisely determine sea level height and track El Niño events. We continue to provide NOAA with state-of-the-art weather satellites that improve our predictive abilities.

In the next few years, NASA will continue to expand our knowledge of the Earth. This year a private company will launch SeaStar, a spacecraft designed to provide NASA will scientific data on life in the oceans—data which may also be marketable to the fishing, oil, and shipping industries. Next year, NASA has planned Lewis & Clark, two collaborative missions with private industry which will provide scientists, businesses, and governments with extremely detailed images of the land. The Lewis mission is an example of a process in which NASA develops the technology enabling the private sector to create new markets: it will use 384 color bands (compared to 7 on Landsat) for close-up land images. In 1997, we will join with the Japanese on the TRMM mission to study tropical rainfall, which is an essential element in the climate change equation.

Landsat: A Proven Record of Accomplishment

In late 1998, we will launch Landsat-7, to continue one of the most important environmental monitoring and research tools we have. The continuation of the Landsat series of measurements is a crucial component of the comprehensive Earth Observing System (EOS) series, focusing on land studies. The Landsat series began in the early 1970's, and has provided the scientific community with a wealth of information on most of the Earth's land surface. Landsat data is stored at the EROS Data Center in South Dakota, which has played a critical role in making the benefits of Landsat widely available. It will continue in this essential role as the Distributed Active Archive Center which houses all of the land data from our missions.

While originally developed as a scientific tool, Landsat has evolved into a practical resource for land managers, farmers, educators, and state and local planners. Once creative users learned what Landsat could provide, they developed ways of translating the data into useful products. Some examples demonstrate Landsat's broad utility:

- The wine industry can use the data to assess insect infestations in their vineyards
- Local governments use the data to predict fire hazardous areas
- Insurance companies use it to assess damage in flood ravaged regions
- States use the data to study local ecosystems, such as the loss of critical marshland which affects fishing and wildlife
- USDA is using the data to measure crop residue which prevents wind and rain erosion

The Best is Yet to Come: The Earth Observing System (EOS)

The key to understanding the integrated Earth system is the Earth Observing System (EOS), scheduled for first launch in 1998. Using a series of different satellites, EOS will look at the Earth in a totally new way: rather than focusing on just one aspect (land or ocean or air), EOS satellites will carry instruments designed to observe multiple aspects of the planet. By getting this kind of information, scientists will be able to see the interactions and enable to move beyond a description of "what" is happening to an understanding of "why."

EOS is the first comprehensive system designed specifically to study the Earth as a complex series of interactions between life, air, water, and land. EOS is composed of 24 essential measurement areas which a consensus of scientists believe will answer the complex questions of climate change. Over a 15-18 year period, EOS satellites will fly in over most of the Earth'ss surface, gathering data such as global changes in the atmosphere, land surface, pollution, and water resources. What were once studied as isolated events will be examined as interconnected and interactive forces which form a comprehensive snapshot of the Earth as a whole.

As in the case of Landsat, the science data from EOS will generate information that will benefit people's lives and livelihoods and certainly provide the opportunity for the commercial sector to develop enhanced data products. Each EOS satellite will provide science information on distinct aspects of the land, atmosphere, water and life that will touch different segments of society—the global understanding will yield local and regional benefits. A sampling of those we can predict with confidence includes:

EOS-AM broadens the scope of Landsat to begin to predict climate change. Its satellite data will provide valuable land images for farmers, businesses, state/local governments

EOS-PM measurements will enable fundamental improvements in climate and weather forecasting, thus giving farmers and others a powerful tool for managing what they plant and when

EOS-CHEMISTRY observations will greatly improve monitoring of air pollution and ozone levels

EOS-ALTIMETRY (RADAR) data will enable us to make precise sea level measurements and determine whether ocean levels are rising, a subject of considerable interest to the 50% of the U.S. population living within 50 miles of a coastline. This mission will also help track and forecast El Niño events

EOS-ALTIMETRY (LASER) readings will accurately measure polar ice sheets and their effect on global climate and sea levels

Of course, neither NASA nor the business community can predict the ultimate marketability of this data with any certainty. But given the types of measurements planned, the positive lessons from Landsat, and the increasing sophistication of the user community, it takes little imagination to think that the science data and understanding we produce today and tomorrow will enable the private sector to develop myriad marketable data products (some of which we can't even project today). Mission to Planet Earth is part of greater research and development investment which is needed by the U.S. to remain competitive in world markets.

And Mission to Planet Earth goes beyond commercial marketability: these scientific endeavors will enable us to begin to answer fundamental, long term questions about the Earth. The ability to forecast climate one or more years in advance will be our most critical capability. Many other important questions are also answered in this quest to forecast climate. Is the sea level consistently rising over time? How do the activities of humans influence the Earth? Can we maintain the progress we have made in protecting the Earth's vital ozone layer? How will the long term climate change? As we piece the puzzle together, answers to these ques-

tions will become clearer and we will enhance the quality of life for ourselves and succeeding generations.

Getting information to people is the key

In this age of information, a state-of-the-art, evolving system to provide data is essential. Mission to Planet Earth has designed the Earth Observing System Data and Information System (known as "EOSDIS") to relay large amounts of information to scientists, educators, governments, businesses, and the general public. Through a series of nine Distributed Active Archive Centers, any data set can be accessed (via the Internet and other means) by thousands of users at the same time throughout the world. As the amount of data and the number of people using the system increases, the system is designed to take advantage of advances in technology to provide timely and comprehensive information.

We need the expertise of people across the world if we are to derive optimal benefit from climate change research. To assist in accomplishing this goal, the EOSDIS is designed to provide our information at the lowest possible cost (the marginal cost of reproduction) to anyone, anywhere on Earth. The more diverse the group of people working on a project, the greater the opportunity for discovery. And the data system may also influence behavior around the world. For example, a Swedish scientist writing a paper on deforestation in Germany may influence a Chinese forestry official to take steps to prevent repeating a harmful situation in his own country.

This low cost data will also be available to the value-added industry. The raw data is enhanced by this industry to provide benefits that reach beyond the scientific community. A local government could develop valuable data to benefit their community or a corporation could target the data for a specific market niche. For example, surburban planners around Seattle could use raw Landsat data to plan the growth of their community into the 21st century. Close-up land images from the Lewis mission (planned for launch next year) and others will eventually help farmers decide the precise amounts of fertilizer to use on their crops. The future uses of this data will be limited only by our imagination.

Just like the Earth, Mission to Planet Earth is ever changing

NASA is always on the forefront of new technology and approaches, and the Mission to Planet Earth program is no exception. While the science foundation of the program—and the fundamental questions it is designed to answer—have not changed, we are constantly examining ways we could improve program implementation. Since the program was approved in 1990, we have reduced the near-term cost (through 2000) of the Earth Observing System by 60% while maintaining the highest priority measurments. We are also looking at ways that we could incorporate evolving technology into the program more readily in the future. NASA is currently conducting studies to examine these questions, as well examining a closer synergy between our activities and those of the National Oceanic and Atmospheric Administration (NOAA). We will be reviewing the results of these studies with the National Academy of Sciences in July. Preliminary analyses by NASA indicate that technological advances and operational efficiences should allow us to reduce the cost of the long term program by 30% (beginning in 2001 and running through the end of the program). While cost savings are essential, we are also committed to continually evolving Mission to Planet Earth into a premier 21st century scientific enterprise.

Moving Forward

The President's FY 1996 budget enables us to move forward with the implementation of this important program (committee's files). From a scientific and practical basis, we urgently need to know the answers to these fundamental questions of climate change. We have, in concert with our numerous domestic and international partners, designed a system of observation and analysis to meet this challenge. We know that, because it is rooted in solid science, this system will provide us with a wealth of near-term benefits and answers to fundamental, long-term climate questions.

Once before, NASA missions and people helped change the way we think about the Earth. Over time, we are confident that the data and information from Mission to Planet Earth will help us and our children think clearly about the world we all live on.

[NOTE—Other materials submitted for the record will be retained in committee files. The Appendix: Mission to Planet Earth Budget FY 1995-1996; Understanding our Changing Planet: NASA's Mission to Planet Earth; Profile of Landsat Data Use:

5 Practical Applications; and NASA's Mission to Planet Earth: Bringing Science Down to Earth]

Senator BURNS. Senator Jon Kyl, I have already introduced the panel. Is there a statement you would like to make at this time? And if you would, come forward and join us.

Although you do not serve on this committee, the full committee, we welcome you.

Senator KYL. Thank you, Mr. Chairman. First of all, is it all right if I sit on this side?

Senator BURNS. You can sit on either side. It does not make a difference.

Senator KYL. I swing from the right side, though. [Laughter.]

STATEMENT OF SENATOR KYL, U.S. SENATOR FROM ARIZONA

Senator KYL. Without comment on that, Mr. Chairman, I really would like to take just about one-and-a-half minutes to make a point. I think what you are doing here is so important.

While I do not serve on this committee, I wanted to especially acknowledge one of my constituents who is here to testify before you, Richard Bowers, who is the City Manager for the city of Scottsdale, and by way of doing that, to just mention one thing that I know ties in directly with what you are trying to do here.

Richard Bowers is the City Manager of the city of Scottsdale, and he is sitting right in the middle of the table there. He has served the city of Scottsdale in the past 17 years as human resources manager, assistant city manager, and now the city manager.

In the April recess of this year, the NASA Administration, Dan Goldin, visited Arizona, specifically, Scottsdale, to commemorate the integration of NASA technologies into Scottsdale's future planning.

Richard's testimony today will cover both the growing needs of that city and the positive results that can be obtained by integrating NASA's remote sensing technologies into Scottsdale's geographic information system.

These new NASA technologies will provide enormous cost savings to Scottsdale for city-operated activities such as mapping and zoning.

His testimony will also reflect the importance of NASA's program Mission to Planet Earth for long-term city planning in a changing global environment. For example, Mission to Planet Earth offers day-to-day operational data necessary for proper city resource management.

I just want to thank you for holding this hearing, for recognizing the importance of this program, and for hearing testimony of some people like Richard Bowers, relating to the exciting projects of the city of Scottsdale in my own state of Arizona.

Senator BURNS. Well, we thank you, Senator Jon Kyl.

I want to apologize to Dr. Kennel. We are all on a tight schedule this morning, and I know Senator Jon Kyl wanted to make this statement this morning.

We appreciate the interruption, and we thank you for coming.

Senator KYL. Thank you. I will, if I might, just sit in the back a little bit and listen until I have to leave here.

Senator BURNS. You are welcome to join us right here, if you want to. Dr. Kennel, I am sorry for the interruption.

Dr. KENNEL. I was delighted to hear the comment.

I think I would like to start our discussion with—can we start with the floods that have plagued the Mississippi and Missouri Valleys in two of the last 3 years. In a scientific sense, those floods started half a world away in a pool of warm water, in the Western Pacific.

When the winds let up, that warm water begins to move, and it moves across the tropical belt of the Pacific, it moves about five miles an hour, and when it arrives at the West Coast of America, the warm water causes the plankton population to decline, and the fish go away, and the Peruvian fishermen call this event the El Niño event, because it occurs around Christmas time.

They do not like it, because the anchovies disappear. The same thing happens to the fish off the West Coast of North America.

Now, this pool of warm water sitting off the West Coast of America rearranges the climate. It causes heavy rains in some places, and heavy droughts in others, droughts and rains over the Coast of California, and it is indirectly, but the basic causative effect of the heavy rains that hit the Midwest in two of the last 3 years.

So we have two "floods of the century" in the Missouri and Mississippi Valleys in those years.

Now, remote sensing from satellites follows this whole progression of events from beginning to end. Satellites absorb the sea surface temperature.

Satellites absorb the winds above the sea surface temperature, and they can predict when this spot of hot water will start moving.

Remote sensing spacecraft and aircraft can observe the extent of those floods, and in the short term provide important data for the planters.

Remote sensing spacecraft, especially the Landsat spacecraft, can characterize the vegetation in the Missouri and Mississippi Valley. It can tell you where the watersheds are and what is going there.

And it is really the Landsat experience that we have had for 23 years with this marvelous flow of data coming over five spacecraft.

It has been piped down to the U.S. Data Center in South Dakota, and then distributed to a variety of users that communicates, as much as anything, the potential of remote sensing in the future. I think my colleagues at the table here will discuss their experiences with Landsat.

The farmers will now begin to understand the possibilities of precision farming. But remote sensing from above does the same thing that it does for scientists.

It enables us to see the complexity and the pattern of their planting, their infestations, the problems they have, see the complexity in their own farm, in their own farming area related to the larger context of their region, and through good science, and climate prediction, to relate all of this to the worldwide pattern of weather and climate that determines what will happen in the future.

And last, NASA will launch Landsat 7 in May 1998 as part of its earth observing system. And NASA is developing new remote sensing techniques during this period that will be very important for land observations.

I know that NASA is downsizing, but this is a scale model of the Lewis Spacecraft. This is going to be launched in 1996. It is a joint project with industry.

They will try to develop a commercial market, and we will try to develop the scientific possibilities of a new instrument that could lead to new capabilities that would supplement the Landsat data stream in vital ways.

It will retrieve high-resolution information, three-meter, ten-foot resolution, but instead of the seven colors of Landsat that it can take pictures in, this will have 384 colors.

You can imagine when you look at somebody's face, you can tell really they are not healthy just by looking at the color of their face. It is the same with the crops.

With 384 colors, you will be able to distinguish the crops, one from another, and the state of their health. Farmers will be able to do that. The scientists will be able to sort out issues related to biodiversity around the world.

So we are exploring this frontier, this new type of hyperspectral frontier together. At the same time, in 1998,

NASA will launch as part of the EOS mission, the A01, a new remote sensing instrument called MODIS, which looks in the other direction.

You can see the whole Mississippi Valley and Missouri Valley with this one remote sensing instrument. It will have a resolution of about a fifth of a mile, and it will work in 34 different colors, a new capability that is designed for us to study the climate, but I think you can see then we will have instruments together, looking at the land, at all different scales.

This new MODIS instrument will be able to come back in a couple of days and tell you what has changed.

So I think if I had to communicate to you one point, it is that in this area of earth remote sensing, there is a convergence between the objectives of the scientists and the practical objectives that the folks who live on the land and live off the land, that they have, they come together.

The same instruments produce scientific information. The same instruments produce practical information.

In 1998, when we begin the earth-observing system, we will begin a new era of land and earth remote sensing, when we will, for the first time, attempt to observe the whole suite of things that determine the earth's climate, the land, the ice, the oceans, the atmosphere.

It will drive them together and will observe them and study them in interaction, and will send the information, independent of scientific discipline, to all the interested users.

The purpose of these observations is to provide the observational basis, whereby, in due course, we may be able to predict the climate and its evolution. Already, people are enthusiastically optimistic that we can predict El Niño events about a year in advance.

We will be able, we think, soon, with some reliability, to say whether next year will be a year of heavy rain or heavy drought, or somewhere in between.

This ought to have a major effect in planting strategies, in the flow of the agricultural futures market, and a variety of other

ways, but these effects will not be realized, unless this prediction, this forecast, is perceived and considered to be reliable, scientifically reliable.

And as we extend our studies, as the years accumulate, and our years of experience accumulate with the earth-observing system, it follows that ultimately we will be able to extend the time over which we can make reliable forecasts.

And so soon, soon, the strong science, which will lead—if the science is strong, then the forecast will be considered to be reliable.

Policy decisions can be made on the basis of reliable information, and commercial and other decisions will also be made. Investment decisions will be made, provided that the science is reliable. This is the essence of the matter.

We believe that the computer models that we will construct, beginning in 1998, we will have the first physically integrated computer model of the climate, these models, with validity and accuracy of the forecast, depend critically on a worldwide, comprehensive set of data.

And that is why the Mission to Planet Earth program has emphasized for so long the need for this comprehensive set of data, as expressed in the Earth Observing System.

Senator BURNS. Thank you, Dr. Kennel. We will go to Dr. Paul Smith, the Director of the Institute of Atmospheric Sciences, at the South Dakota School of Mines and Technology, the area where aces and eights were made famous. Dr. Smith, thank you for coming this morning.

STATEMENT OF PAUL SMITH, DIRECTOR, INSTITUTE OF ATMOSPHERIC SCIENCES, SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

Dr. SMITH. Thank you, Mr. Chairman. Thank you for this opportunity to appear before you to discuss the NASA Mission to Planet Earth program.

I also have submitted a prepared statement, which I would like to have entered into the record.

Senator BURNS. By the way, I will tell you, you may summarize your statements, if you so choose. We will have some questions for you, but your complete statement will be made part of the record.

Dr. SMITH. Thank you, sir.

I also hope that if I report that I have a son who is a graduate of Montana State University, it may add some weight to my testimony.

Senator BURNS. Quite a lot. [Laughter.]

Dr. SMITH. Through research going on in my Institute at the South Dakota School of Mines and Technology, and through my involvement in the South Dakota Space Grant Consortium, I have had the opportunity to become familiar with the Mission to Planet Earth as well as other NASA programs.

As you know, major concerns that affect the Upper Missouri Basin, in which my home institution is located, include weather, water, and agriculture.

The observations from Mission to Planet Earth have impact upon all of these concerns, as Dr. Kennel suggested, and in a sense, the

Mission to Planet Earth is NASA's most important program to this region.

The data from Mission to Planet Earth provide a basis for a greater understanding of the processes involved, the linkages among those processes, and a better basis for public policy decisions that may affect our region.

I would like to emphasize a few points in support of this position. First, one thing required is to have efficient access to the data coming from the Mission to Planet Earth.

The Scientific Assessment and Strategy Team that was assembled at the EROS Data Center, following the 1993 floods in the Midwest, which, regrettably, we see again this year, provides an example of what can be done when the data are accessible and organized in a framework that permits efficient access and use by agencies and decisionmakers.

The second point is, developing the applications for these data does not really require spinoff technological developments in the way that much of NASA's program leads to applications, but I think it does require the development of capable personnel.

We have been working to try to educate geologists and hydrologists in the use of remotely sensed data, such as comes from space platforms like Landsat and EOS.

These efforts are now giving skilled people, who are beginning to synthesize knowledge about the atmospheric, the surface water, and the groundwater components of the hydrologic cycle, into coupled models of the kind that Dr. Kennel mentioned.

Such models can describe the interrelationships among the components, and thereby maximize the benefits from the Mission to Planet Earth and the Earth Observing System program.

And finally, I would like to briefly mention the Global Energy and Water cycle Experiment, known as GEWEX, and particularly, a planned northwestern large-scale area study of the GEWEX Continental-scale International Project, or GCIP, another part of this familiar alphabet soup, to be carried out in the Upper Missouri River Basin a few years hence.

By that time, we will see Landsat 7, and the earliest of the Earth Observing System satellites in orbit. We look forward to the opportunity to try to incorporate the measurements from these satellites into studies of the hydrologic cycle in our region.

Thank you for your attention, Mr. Chairman.

Senator BURNS. Thank you, Dr. Smith.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF DR. PAUL L. SMITH

INTRODUCTION:

Mr. Chairman, Members of the Committee, I am Paul L. Smith, Director of the Institute of Atmospheric Sciences at the South Dakota School of Mines and Technology located in Rapid City, South Dakota. I am also the Director of the South Dakota Space Grant Consortium, an entity that involves participation from the South Dakota State University and the U.S. Geological Survey's EROS Data Center as well as my home institution. Through the latter connection as well as research projects going on in my Institute, I have had the opportunity to become familiar with various NASA programs, including the Mission to Planet Earth. I thank you for this opportunity to discuss with you how the activities of the Mission to Planet Earth will impact the citizens and the economies of the Upper Missouri River Basin.

The major concerns affecting the economy of this region can be stated in three words: weather, water, and agriculture. My Institute has been involved in studies

of the weather and climate processes in the region for over 30 years. The concerns about water are well known to most of you; the usual situation seems to be that we have either too little or too much. Scientists in the Institute have come to realize that our studies must extend beyond simply the weather conditions that lead to moisture on the ground; we need to increase our understanding of how the surface and underground processes affecting the transfer of water are coupled with the atmospheric processes. Those processes in turn drive the major economic factor in the region, the highly productive agricultural sector. Observations from the Mission to Planet Earth have impact on all of these concerns.

IMPACT OF MISSION TO PLANET EARTH:

The Mission to Planet Earth is NASA's contribution to the Global Change program, but its observations have much broader application. Data being acquired by the Mission to Planet Earth program, and to be greatly enhanced when the series of Earth Observing System (EOS) satellites begins flying in the late 1990's, offer great promise to the Upper Missouri River Basin region. The data provide a basis for greater understanding of the processes involved as well as a firmer base for public policy decisions affecting the region. A good example of how this can work is afforded by events following the disastrous Upper Mississippi Basin floods of 1993, which regrettably seem to be recurring in many places this year. A group of agencies assembled a Scientific Assessment and Strategy Team (SAST) at the EROS Data Center near Sioux Falls, South Dakota, to compile a data base that could be used to better deal with the impacts and the consequences of such flooding. The digital data base assembled by this Team integrates more than 100 digital maps and linked data bases in a standardized Geographic Information Systems (GIS) framework. This provides an excellent basis upon which to super-impose the observations coming from the Mission to Planet Earth. More and more agencies are gaining the capability to work with data in this GIS format, so the observations can be incorporated readily into their applications.

Developing the various applications for such data requires a cadre of educated and experienced people. As one part of our Space Grant Consortium program, we have been sending Summer Faculty Fellows from the member universities to the EROS Data Center to obtain increased familiarity with the types and the uses of remotely-sensed data. The group has included image processors but also geologists and more recently hydrologists, who have gained the expertise needed to make use of the remotely-sensed data in their various fields of knowledge. As an outgrowth of this activity, we have recently instituted two efforts to couple the atmospheric, surface water, and ground water components of the hydrologic cycle together. One is a new joint doctoral program in Atmospheric, Environmental, and Water Resources, conducted by the two Consortium member universities with students from the several relevant departments in each university. A parallel effort to improve our capability to describe and analyze the processes using coupled atmospheric-hydrological models has been initiated as part of the National Science Foundation's EPSCoR activity in the State of South Dakota. Thus, we are preparing the scientists and the methodology needed to integrate the observations from the Mission to Planet Earth into the kind of coupled models that will be required to understand the linkages among the various processes. The Consortium has also proposed that a visiting-scientist-type program be established in conjunction with the EROS Data Center to broaden the scope of this activity. The "EROSpace Institute" would welcome personnel from federal, state and local agencies, as well as university and other scientists, into this program. Success in all of these efforts will depend in large measure upon efficient access to the data being obtained by the Mission to Planet Earth.

The planned EOS product list includes something over 200 individual products, designed largely to serve the needs of the EOS science community. However, this valuable program will fall short of its promise unless the observations it collects can be made accessible to a wider community of users, including applications-oriented persons and policy makers. The EOS constellation of satellites will produce a great deal of data; the need is to convert this into information expressed in a format suitable for the needs of diverse users. There are many avenues through which this can be accomplished, but we see it as an essential element in maximizing the benefit to be obtained from the Mission to Planet Earth.

GEWEX and GCIP:

Finally, NASA is a participant in an on-going international program known as the Global Energy and Water Cycle Experiment (GEWEX). The program intends to address the issues of water and energy balance on a global scale, but much of the ground work will have to be done at a regional scale before the global-scale issues can be addressed. An initial part of this is the GEWEX Continental-scale International Project (GCIP) now getting underway with focus on the Mississippi River Basin of North America. The initial work is being done in the southwestern "Large-

Scale Area" (LSA), focusing on the Arkansas and Red River Basins, because of existing infrastructure already available or being implemented there. The emphasis will shift in a couple of years to the North Central LSA, which includes parts of the Upper Missouri and Upper Mississippi River Basins. The third area of interest will be the northwest LSA, which comprises essentially the Upper Missouri River Basin. As the focus moves to this region a number of considerations peculiar to the area will arise; snow in the mountains will be a major concern, and the coupling to ground water will be of greater concern than in the earlier LSA regions. Much of the early work in GCIP must be based on currently existing or soon-to-be-implemented observing systems, such as the GOES series of satellites. By the time the focus shifts to the northwestern LSA, however, the earliest of the EOS satellites will be in orbit. That will provide a new observing capability which can be important to the success of the studies in this region. We look forward to the opportunity to study these observations and make use of them in understanding the weather and water issues of our region.

CONCLUSION:

I would like to conclude by thanking you once again for this opportunity to talk to you about some of the concerns of the Upper Missouri River Basin. I urge you to provide the support needed to help make the Mission to Planet Earth achieve its full promise.

Senator BURNS. Richard Bowers, City Manager, Scottsdale, Arizona.

STATEMENT OF RICHARD BOWERS, CITY MANAGER, SCOTTSDALE, ARIZONA

Mr. BOWERS. Mr. Chairman, thank you very much for the opportunity to be here this morning to testify, and a very special thanks to our distinguished Senator Jon Kyl, from Arizona, for his kind introduction, and all the work he has put into our current relationship with NASA, which we believe not only has produced benefits to date, but is the foundation for a great future.

Maybe I could summarize my comments. They will not be technical in nature. We would like to comment on what we believe to be an incredible opportunity to harness the technology of outer space in service to communities.

The Mission to Planet Earth is central to our long-term strategy for sustainability, whatever that means, ultimately, in our communities.

We are going to need the most sophisticated of tools to meet with the most complex of problems. This technology of the Mission to Planet Earth provides that, in our opinion.

Why Scottsdale, why me, to testify? Why would the city manager make these comments? I think, starting with me, because I care about the future.

I see the world through the eyes of our children, and believe that the ultimate measure of my success and our communities' success is going to be if our grandchildren say we have done it right, and made bold, courageous decisions that serve the future, not just the present.

I also know a good thing when I see it. I have been in this business for 25 years, and I see within the Mission to Planet Earth the opportunity to provide data, which can result in intelligence, which will raise the quality of public dialog, which will ultimately raise the quality of public decisions, which, frankly, takes outer space technology right into the living rooms of people, and into the neighborhoods, and into the shaping of community.

Why Scottsdale? Scottsdale is a community that is only one-third built out. It would be hard to represent us as the typical American

community, but we have many, many characteristics in common, and many, many concerns.

We are 160,000 population. We will build out somewhere in the neighborhood of 350,000. We are 185 square miles. We have a very sensitive ecosystem, a mountain system within our community.

In fact, 3 weeks ago, just about now, our citizens made the decision to tax themselves in order to purchase the McDowell Mountain land and surrounding desert, not for any economic reason, they will not drive on it, they will not be able to read it, it is not another public building, it is a gift of future generations.

That kind of view of the future is, in effect, why we believe and know that the Mission to Planet Earth data can be leveraged in support of our community, and, frankly, I believe many other communities.

We sort of live by the adage that, to paraphrase Einstein, that we will not solve the problems of today at the same level of consciousness that got us into them. And that is why the Mission to Planet Earth's technological capability is center point to our strategy for the future.

We worry about the same things that other communities worry about, Mr. Chairman. We worry about traffic, and air, and water, about the quality and supply. We worry about floods.

Now, within the last couple of weeks, we have started to worry about killer bees and fire ants. We also worry about tomorrow, and we want Scottsdale to be a very good place to live.

Over the past year, we have explored many possibilities with NASA and the linkage of their remote sensing data to our GIS system.

And we have already begun to produce some tools which are illustrative of that point, and I believe representative in the material that we gave you in advance, that the capacity, through spectral imaging, represents different characteristics of land use and different characteristics of the topography, and the flora, and the fauna.

The McDowell Mountain imagery gives us extraordinary data, which we have never had before. That data is critical to us at this point in our evolution to make wise and prudent decisions, stewardship decisions, about the future.

We are not looking for a sustained long-term dependency relationship, we are looking for a technological jump-start. We have great belief that industry will pick up on the opportunities of the Mission to Planet Earth technology. In fact, there is a marketplace for it.

We are proud in Scottsdale to have the opportunity to be a pilot, but just that, a pilot to represent to others what can be done, and we believe strongly that there is a business opportunity that will emerge for private industry from this effort.

We have sought Federal funds through competitive grants, with no congressional earmarks, and we also bring to that, local community funding, and private dollar support.

Mr. Chairman, as the city moves forward with its advanced technology program, we believe that having access to NASA's Mission to Planet Earth program data is essential to our success.

In the short term, cities like Scottsdale need accurate operational data for effective day-to-day management of local resources. In the long term, local leaders, such as my city council, need assistance, as we all do, in making decisions in the context of a changing global environment.

Scottsdale is a rapidly growing city. We are constantly looking for ways to create sound policy for future generations, rather than providing a quick fix to problems.

Again, we need the data to produce the intelligence to raise the quality of public dialog to produce, inevitably, better public decisions that serve the future.

I would like to take a moment to put Scottsdale's interests in the Mission to Planet Earth in perspective, and to provide an example of the potential impact on city operations.

Currently, we spend about $45,000 per square mile to perform a drainage plan. With 185 square miles in the city, one-third built out, we have about $5 million to $6 million of drainage plans left to do.

For this single application, which looks at all sorts of things, from the type of vegetation, the condition of paving on roads, to the slope of terrain, to the geology of the soil, to the location and quantities of water. WE would spend $5.6 million.

While this figure may be a bit on the high end, I am not certain it is by no means uncommon to other communities.

We believe strongly, through our analysis, and you will see attached to the material we sent ahead, a chart of where we believe our savings are to come from, that we can cut 50 percent off of that cost by the application of the Mission to Planet Earth technology, Mr. Chairman.

That brings it right down home to the neighborhoods, and allows the distribution of those resources to other vitally needed programs within our communities.

Whenever I talk technology, Mr. Chairman, I sure better consult my notes. We know that NASA has the technology and instrumentation to determine these characteristics, as I mentioned, at half the price.

We are particularly pleased with such instruments as the ASTER 15-meter multi-spectral sensor, the Landsat 7, the radar altimeter, and the Small Sat program, all which will be perfected in the next few years, and be invaluable to local and regional governments in their planning and mapping activities.

We really believe, also, that, not only for Scottsdale and other communities similarly situated, is there a benefit, but we believe strongly that such agencies as FEMA, the Corps of Engineers, and DOT can apply these same technologies to their economic and operational benefit.

We have a complex future, Mr. Chairman. Each day our community makes decisions that will shape tomorrow. Some of them are irrevocable. All of them have implications for the future.

The Mission to Planet Earth creates an exceptional opportunity for us to use data to allow us to make those decisions in a more comprehensive, effective manner.

Frankly, Mr. Chairman, we are not looking for a long-term subsistence relationship, we need a technological jump-start.

Our efforts in Scottsdale, our long-term plan for the management of our community, and our efforts at sustainability will not be successful without the leverage of technology.

The Mission to Planet Earth brings that technology to us in a fashion that will help us get it going. It will help us get on the map with a comprehensive, long-term effort toward sustainability.

We need that help, and I guess I could best characterize it, in order that we could fulfill what you expect from us at the local level, in responding to the direction, to take down to the neighborhoods and down to the communities, the responsibility for shaping our future.

So I appeal to you, Mr. Chairman, to recognize that the Mission to Planet Earth provides the tools, it provides the encouragement to imagine, it helps us with the will to change, and it gives us the tools to excel in shaping the communities of tomorrow.

I suppose it would not be appropriate for me to come this distance and share these thoughts with you without sharing from a personal perspective.

I have five children, two daughters-in-law. Peggy and I have been married 28 years. Our children range from age twenty-six to 2 years old.

I see the future through their eyes, and I expect soon to see the future through my grandchildren's eyes.

We have many choices that we need to make today that are urgent, that represent immediate needs of the moment; however, we cannot lose sight in the needs of the moment for the needs of the future.

I look forward to the Mission to Planet Earth as being something that my son, Harrison, who is two, will sit back, when he is my age, and be very appreciative of the fact that we applied this technology to shaping his future.

I thank you very much for your time.

Senator BURNS. Thank you, Mr. Bowers. We appreciate those comments.

[The prepared statement of Mr. Bowers follows:]

PREPARED STATEMENT OF RICHARD A. BOWERS

Mr. Chairman and members of the subcommittee, thank you for the opportunity to testify before this panel today.

Mr. Chairman, you may wonder why a City Manager of a city with no NASA facilities would be interested in testifying on behalf of NASA programs, and so I would like to provide some background into our unique relationship with this agency. While no resident of Scottsdale would claim that it is a typical American city, it does have challenges typical of any city. We are a community of 160,000 located east of Phoenix, covering 185 square miles. Only one-third of our land is developed and the City is growing rapidly. We have traffic congestion, we worry about water supplies, and we face potentially enormous costs to keep our citizens' air and water clean and keep them safe from flooding. We are committed to making sure our City remains a good place to live.

Over the past year, we have explored the possibility of integrating NASA remote sensing technologies into the City's Geographic Information System and found that it has enormous potential to save the City millions of dollars each year in the costs of city-operated activities such as planning, zoning, mapping, as well as dealing with environmental laws such as the Clean Air Act and Clean Water Act. I have included a chart with my written testimony that outlines areas in which the City may realize savings from the use of this remote sensed data. The City is in the process of working with private industry to develop a system using NASA technology that will as-

sist local and regional governmental entities across the country to reduce current operation costs and plan for the future.

However, I must stress that Scottsdale does not want to be in the space business on a permanent basis and we view this relationship with NASA as a temporary one. We are interested in improving services for our citizens, and if we can do so by serving as a pilot to demonstrate that NASA technology can successfully be brought to American communities, all the better. Eventually, we will look to private industry to take advantage of a significant market and make this technology available to all communities.

We believe that Scottsdale's current relationship with NASA is an excellent example of how a Federal-local partnership should work. The agency has a well-documented mission to bring their technology closer to the daily lives of Americans, and they understand that communities such as Scottsdale are well suited to assist with this endeavor. The City has requested Federal funding for its Advanced Technology Program through competitive grant opportunities and has not sought congressional earmarks. We have made local contributions to the project and have looked to private sources of funding as well. And, because we believe that the eventual market for this technology will make it self-sustaining, we do not plan on seeking Federal assistance each and every year.

As the City moves forward with its Advanced Technology Program, we believe that having access to NASA's Mission to Planet Earth program data is essential to its success. In the short-term, cities such as Scottsdale need accurate operational data for effective day-to-day management of local resources. In the long-term, local leaders need assistance in making decisions in the context of a changing global environment. Scottsdale is a rapidly growing City and we are constantly looking for ways to create sound policy for future generations rather than providing a quick fix to problems.

To put Scottsdale's interest in the Mission to Planet Earth program into perspective, I would like to provide an example of its potential effect on city operations. Currently, our community spends approximately $45,000 per square mile to perform a simple drainage plan. With 185 square miles in the City, the potential costs to the City are about $8 million for this single application. While this figure may be on the high end for many communities, it is by no means uncommon.

Much of the expense is incurred in determining land surface characteristics. Some of the essential data that a city such as Scottsdale needs in this area includes: the types of vegetation that exist in certain areas; the condition of pavement on roads and parking lots; the slope of the terrain, particularly in the mountainous areas surrounding the city; the geology of the soil; and where water exists, and in what quantities, which is a particular concern of the arid west.

We know that NASA has the technology and instruments to determine these characteristics at half the price that it costs Scottsdale. Instruments such as the Aster 15 meter multi-spectral sensor, Landsat 7, the radar altimeter, and the Smallsat program will all be perfected in the next few years and would be invaluable to local and regional governments in their planning and mapping activities. In addition, we believe that this technology would be of use to other Federal agencies such as FEMA, the Corps of Engineers, and the Department of Transportation to reduce regulatory and management costs for themselves and state and local governments. The City is already working with EPA on possible uses for this technology.

The Mission to Planet Earth program is the only program to our knowledge that could provide the information essential to place local decisions in a local context. Each day, communities make decisions that will shape their infrastructure, economies and neighborhoods for the next century, but have few tools to provide them with global and regional models of what the future may look like. The Mission to Planet Earth program is a superb opportunity to focus technical resources on a city such as Scottsdale's whose fundamental obligation is to provide stability and security for its citizens.

The City of Scottsdale's Advanced Technology Program has not received any funds specifically from the Mission to Planet Earth program to date, but we see it as a logical next step in our progression and do plan on submitting proposals in the future. However, even if Scottsdale does not receive a penny in direct Mission to Planet Earth funds, we believe that it will be a valuable tool for all local communities in the future and the indirect benefits will be just as substantial. NASA's mission is critical not only to the scientists who perform this valuable research, but also to entities such as cities who may have many uses for the important data supplied by programs such as Mission to Planet Earth. We urge you to resist the temptation to reduce funding for this important program that will mean so much to our future.

Thank you again for the opportunity to address the subcommittee and I would be pleased to answer any questions you may have.

[Mr. Bowers' City of Scottsdale GIS Related Applications for Image Processing System Charts 1 of 3 follows:]

City of Scottsdale
GIS Related Applications
For Image Processing System

	EXISTING								FUTURE						BENEFITTING CITY DEPARTMENTS									1
	1 FT DTM	1 FT COLOR AERIAL	80 M LANDSAT	30 M LANDSAT	15 M LANDSAT	20 M SPOT	10 M SPOT	5 M HIGH RES	1 M HIGH RES	30 M INFARED	5 M INFARED	30 M RADAR	5 M SPECTRAL	WATER	SEWER	TRANS	PLANNING	DRAINAGE	ENVIRON	POLICE	FREQUENCY	COST SAVINGS
SURFACE MEASUREMENTS:																							
NON POINT DISCHARGE ELIMINATION SYSTEM	M			M			M		O	M	O			X				X	X		Y	$1.8 MILLION
DATA INPUT TO GIS SYSTEM:																						$1.5 M/10 YRS
BUILDING FOOTPRINTS		M							O					X	X	X	X	X	X		Y	
STREETS (TO INCLUDE TYPE OF STREET IE. ASPHALT)		M							O				O	X	X	X	X	X	X		Y	
SIDEWALKS		M							O				O	X	X	X	X	X	X		Y	
POOLS		M							O				O	X	X		X	X	X		Y	
MANHOLES		O							O					X	X	X					Y	
CACTUS		M							O				O			X	X		X		Y	
VEGETATION COVERAGE (IE. DESERT SHRUB, PINE ETC..)				M									O	X	X	X	X	X	X		Y	$67 MILLION
LANDUSE	M	M		M			M		O	M	O	O	O	X	X	X	X	X	X		Y	
SOIL TYPES				M					O	O			O	X	X	X	X	X	X		Y	
CHANGE DETECTION (URBAN GROWTH, VEGETATION, ETC..)			M	M			M		O	M	O		O				X		X		Y	
ENVIORNMENTALLY SENSITIVE LAND ORDINANCE	M	M					M	O		M	O		O	X	X	X	X	X	X		Y	
GROWTH IMPACT OF NEIGHBORING CITIES				M			M	O						X	X	X	X	X	X		Y	
SURFACE WATER MANAGEMENT	M	M						O		M	O	O	O	X	X	X	X	X	X		A	$ M/YR
SOCIAL HEALTH OF NEIGHBORHOODS								M		M	O						X		X	X	Y	
DISASTER ANTICIPATION/MANAGEMENT																						
FIRE/FLOOD PREDICTION/IDENTIFICATION									M				O	X		X	X	X	X	X	A	
FLOOD/FIRE MONITORING/REACTION/REMEDIATION									M				O	X		X	X	X	X	X	A	$10 M/10YRS
FLOOD/FIRE DIRECTION OF GROUND BASED TEAMS									M				O	X		X	X	X	X	X	A	

NOTE: DTM and Color Aerial Photos are presently being developed for the city with a completion date of June 95.

For Landsat, Color Photography and SPOT images, P represents possible useage, M = Minimal requirement, and O = Optimal requirement.

For Frequency Y = Yearly analysis, W = Weekly, H = Hourly (or better), and A = As needed

City of Scottsdale
GIS Related Applications
For Image Processing System

	EXISTING								FUTURE						BENEFITTING CITY DEPARTMENTS									2
	1 FT DTM	1 FT COLOR AERIAL	80 M LANDSAT	30 M LANDSAT	15 M LANDSAT	20 M SPOT	10 M SPOT	5 M HIGH RES	1 M HIGH RES	30 M INFARED	5 M INFARED	30 M RADAR	5 M SPECTRAL	WATER	SEWER	TRANS	PLANNING	DRAINAGE	ENVIRON	POLICE	FREQUENCY	COST SAVINGS
SURFACE MEASUREMENTS (CONT):																					Y	
URBAN HEAT ISLAND		P					M				O			X		X	X		X		Y	
LANDFILL MONITORING		P					M						O				X		X		Y	
UNAUTHORIZED DUMPING DETECTION		P					M						O	X		X	X	X	X		Y	50K/YR
ALLEY PAVEMENT EVALUTION		P					M						O			X	X		X		Y	25K/YR
ENERGY CODE COMPLIANCE		P					M				O						X		X		Y	
ENERGY MANAGEMENT ANALYSIS		P					M						O				X		X		Y	
TRANSPORTATION MONITORING AND ANALYSIS																						
TRAFFIC COUNTS/LEVEL OF SERVICE		P						M	O		O					X	X		X	X	Y	
CLEAN AIR ACT CONFORMITY		P						M					O			X	X		X		Y	$5 MILLION
TRAFFIC GRID LOCK									M							X			X	X	H	
EMERGENCY VEHICLE ROUTING ASSISTANCE									M							X			X	X	H	
ABANDONED/STOLEN VEHICLE IDENTIFICATION (IN DESERT)									M							X			X	X	A	25K/YR
SEARCH AND RESCUE ASSISTANCE (DESERT, PARKS ETC.)											M					X			X	X	A	
CIVIL DISORDER (PATH AND FLOW OF CROWDS)									M							X				X	A	
ZONING AND CODE ENFORCEMENT									M				O				X	X	X		W	200K/YR

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City of Scottsdale
GIS Related Applications
For Image Processing System

	EXISTING							FUTURE						BENEFITTING CITY DEPARTMENTS									3
	1 FT DTM	1 FT COLOR AERIAL	80 M LANDSAT	30 M LANDSAT	15 M LANDSAT	20 M SPOT	10 M SPOT	5 M HIGH RES	1 M HIGH RES	30 M INFARED	5 M INFARED	30 M RADAR	5 M SPECTRAL	WATER	SEWER	TRANS	PLANNING	DRAINAGE	ENVIRON	POLICE	FREQUENCY		COST SAVINGS
AIR MEASUREMENTS:																							
POLLUTANT SOURCES AND MOVEMENTS		P					M							O		X	X		X		Y		
AIR SHED MODELING		P		M										O		X	X		X		Y		
FIREPLACE AIR QUALITY IMPACT		P		M										O			X		X		Y		
PARTICULATE MONITORING		P		M										O			X		X		Y		
AIRBORNE CHEMISTRY		P		M										O		X	X		X	X	Y		
CLANDESTINE DRUG OPERATION IDENTIFICATION													M						X		Y		
SUBSURFACE MEASUREMENTS:																							
SOIL MOISTURE				M										O	X		X	X	X	X		Y		
WATER TABLE MONITORING	X					M							O		X		X	X	X	X		Y		
LEAK DETECTION (UNDERGROUND STORAGE TANKS)				M					M					O	X			X	X	X		Y		
PIPELINE LEAKS (WATER, SEWER, ETC.)		P				M								O	X	X	X	X	X	X		A		
TOTAL POTENTIAL COST SAVINGS:																							11.5M/YR

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and O = Optimal requirement

For Frequency Y = Yearly analysis, W = Weekly, H = Hourly (or better), and A = As needed

Senator BURNS. Now, we will hear from Mr. Al Watkins, who is Chief, National Mapping Division, of the United States Geological Survey.

Thank you, Mr. Watkins, for coming this morning.

STATEMENT OF AL WATKINS, CHIEF, NATIONAL MAPPING DIVISION, UNITED STATES GEOLOGICAL SURVEY

Mr. WATKINS. Thank you, Mr. Chairman. It is a pleasure to be here.

I also have a longer statement, which I will submit for the record. I will summarize briefly.

I would also, before I start, like to thank both you and Senator Larry Pressler, from South Dakota, Chairman of the full committee, for dealing with this substantive and important issue.

Thank you for the opportunity to appear before this committee to lend my support and that of the U.S. Geological Survey to preserving a strong Earth Observing System, including an effective data and information system capable of serving a large and diverse community.

The U.S. Geological Survey, a science bureau of the Department of the Interior, endorses both the concept and the current design of the Earth Observing System.

The truth about ongoing complicated issues regarding the degree of human impact on the earth's environment cannot be known without further research and study, and systematic collection and analysis of various types of earth science data on a worldwide basis is practical only by means of observation from space.

The U.S. Geological Survey believes that the EOS land instruments, some of which have been mentioned here today, including MODIS, ASTER, MISR, and those on Landsat 7, will provide new and improved data in terms of the spectral characteristics and the spatial resolution to scientists and to a much broader user community of operational users.

For this, however, to happen in an efficient manner, it is critical that the integrated data receiving and distribution capabilities of the EOS data and information system, or EOS–DIS, are fully implemented as planned and designed today.

The Geological Survey operates the EROS Data Center in Sioux Falls, South Dakota, and, over the last 22 years, this Center has had more experience dealing with customers interested in the availability of remotely sensed land data than any other civil institution in the world.

In this last year, our EROS Data Center received more than 100,000 inquiries about its archive holdings, and filled nearly 25,000 orders for data. Over 70 members, out of a staff of something over 400, located at the center, are engaged full time in satellite remote sensing data research and applications to land processes.

With its legislative mandate for the National Satellite Land Remote Sensing Data archive, the U.S. Geological Survey is in an appropriate position to understand and fully support the requirements for a successful EOS program, especially in terms of its ground processing and distribution procedures.

If I leave you with one thought, it would be that history shows that poorly implemented ground systems, or compromised ground systems that provide access to satellite data, can have devastating long-term impacts on the quality of scientific research, on the operational uses of remote sensing data, and on the ultimate benefits that we receive from these large expenditures in space.

Mr. Chairman, EOS data will provide the key for sorting out pressing questions about the interactions of the atmosphere, oceans, and continents, as Dr. Kennel described, and our impact upon them.

EOS data will also have great potential for addressing important practical problems throughout the public and private sectors.

The Department of Interior and the U.S. Geological Survey will continue to work closely with NASA and other EOS partners to ensure that the scientific goals and practical objectives of Mission to Planet Earth and the Earth Observing System are realized.

As we deal with very tight budgets these days and the budget deficit, I think Mission to Planet Earth, with its plan to deal with and utilize fully the facilities of other government organizations, is key to an efficient and economical ground-processing system. That partnership exists between the U.S. Geological Survey and NASA.

The U.S. Geological Survey, over the last 2 years, has spent $10 million constructing a building that will house all of the sophisticated computer equipment and the archives for Mission to Planet Earth, and looks forward to continuing to play a key role in making this data available to all of the user community, both operational and scientific.

Thank you, Mr. Chairman.

Senator BURNS. Thank you, Mr. Watkins. I will have a couple of questions for you in just a little bit.

[The prepared statement of Mr. Watkins follows:]

PREPARED STATEMENT OF MR. ALLEN H. WATKINS

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before this Committee to lend my support, and that of the U.S. Geological Survey, to preserving a strong Earth Observing System (EOS), including an effective data and information system capable of serving the needs of a large and diverse user community.

Mission to Planet Earth (MTPE) and EOS have been promoted primarily on the premise that they are the program and tool whereby scientists will be able to study the Earth as a unified system, leading to better understandings of the interactions among atmosphere, land, and ocean processes and to the scientific basis needed for making informed policy decisions related to human influence on the changing planetary environment. These remain fundamental potential contributions of EOS, which I will address further. However, it also is important to recognize that in addition to the significance of EOS in characterizing and better understanding Earth processes, the data from EOS potentially have many important practical applications throughout the public and private sectors.

For more than two decades now, the U.S. Geological Survey's EROS Data Center (EDC), located near Sioux Falls, South Dakota, has been collecting, processing, archiving, reproducing, and distributing a variety of satellite and airborne remotely sensed data of the Earth to research and operational users. In 1994, the EROS Data Center received more than 100,000 inquires about its data holdings from a vastly diverse population of potential users, and it filled more than 25,000 orders for those data. Sixty-five percent of those orders went to commercial or individual private users, who utilized the data in a wide range of applications. Such applications included exploration for petroleum and mineral resources in the United States and around the world, transportation and utilities routing, and crop monitoring, to mention just a few. Twenty-four percent of data orders from EDC in 1994 were made

by the Federal government in support of research and operational projects, such as forest, cropland, and rangeland vegetation monitoring, fire-fuels mapping of public lands, and geologic mapping to assess our country's mineral resources. Other categories of users include university researchers and operational users in State and local governments.

Remote sensing data management and distribution functions fit well within the U.S. Geological Survey's mission—to obtain and disseminate objective Earth science data and information—and the Geological Survey strongly endorses NASA's multiagency design for managing data processing and dissemination for the EOS Data and Information System (EOSDIS).

EOS land remote sensing instruments will provide new and improved data, in terms of spectral characteristics and spatial resolution, compared to the data provided by today's land remote sensing satellites. Consequently, the expanding applications that industrial and other commercial users have been developing for land remotely sensed data will continue to grow if efficient access to EOS data is assured. EOS data that characterize the oceans and atmosphere will also have other important applications. We can predict that EOS data will be important to the commercial fishing industry. They will also be important to the maritime shipping industry, and even to the airline industry as, for example, when major volcanic eruptions spread ash plumes through the sky.

Healthy debate is currently being waged regarding the degree to which human activity is having adverse effects on the Earth's environment. The truth about the issues which are central to this debate cannot be known without further research and study. Consequently, it seems only reasonable that we should seek diligently, yet cost effectively, to obtain the necessary data and information for all investigators and policymakers.

Such improved understanding requires systematic collection and analysis of various data on a worldwide basis, and space observation is the only practical means for collecting many of these data. Mission to Planet Earth, in general, and EOS, specifically, are critical elements of the United States' efforts to meet this enormous challenge. EOS will provide the space platforms and sensors to collect the relevant data; it will include the data and information systems to process and distribute data to the science community, and it will incorporate a research program to lead the scientific research and data analysis efforts at answering compelling questions of planetary proportions.

History shows that poorly implemented ground receiving systems that provide access to satellite data can have devastating, long-term impacts on the quality of scientific research and operational uses of remote sensing data.

Mr. Chairman, EOS data will provide the key for sorting out pressing questions on humanity's impact on our planet; they will also have great potential for addressing many important practical problems throughout the public and private sectors. The integrated ground data processing and distribution system—EOSDIS—must be appropriately designed, funded, and implemented to provide easy access to EOS data by the broad community of users. The Department of the Interior and the U.S. Geological Survey will continue to work closely with NASA and other EOS partners to ensure that the scientific goals and practical objectives of Mission to Planet Earth and the Earth Observing System are realized. Thank you, Mr. Chairman.

Senator BURNS. We have Tommy Thompson, Resource Manager, from Louisiana–Pacific Corporation. And I want to thank you for coming forward, Mr. Thompson.

I have more than a passing interest in the wood products industry and how we use new sciences in growing and harvesting one of the most important crops I think we have. So I appreciate you coming today.

STATEMENT OF TOMMY THOMPSON, RESOURCE MANAGER, LOUISIANA–PACIFIC CORPORATION

Mr. THOMPSON. Thank you, Mr. Chairman.

On behalf of Harry Merlo, President and CEO of Louisiana–Pacific, and Robert Simpson, our general manager of the western division, our over 13,000 employees nationwide, and myself, let me say that I appreciate the opportunity to provide this testimony.

I will try to shed some light in our application of the technology and our use and implications of it.

To meet the demands for the needs in managing and monitoring the diverse forested landscapes owned by Louisiana——

Pacific in a timely and cost effective manner, we are utilizing satellite imaging to help us in the process.

The satellites have the ability to give us the top down broad landscape views that more accurately define and describe the numerous forest stand types that we have, as well as evaluate the current and past timber stand conditions.

The watershed resources become easily recognizable on this broad landscape basis. Without satellite technology, you tend to lose that broad overview.

In addition to the current data, we integrate with our GIS system, as the other presenters have talked about, the other information that we bring in, ownership, roads, streams, watershed data—we rely on the satellite imagery to give us the landscape overview. We can bring in the vegetation across that landscape.

We use this as a basis for developing our sustained yield management plans. It gives us a broad context to look at forests as they exist and will exist into the future. The important facts are the data that comes in from the satellites is an unbiased overview.

Past technologies relied on physical human ocular estimates. The satellite eliminates the biases that human eyes put on the landscape. It also gives us a repeatable nature in consistency, and over time we can develop good comparisons with integrating that with GIS, (Geographic Information Systems.

That tells us where we were, where we currently are, and were we are going to be in the future. It gives us the monitoring tools to show that our forest practices are leading us in the right direction for sustainability of all forest resources, not only the trees, the wildlife, the fisheries that rely on the forest.

It gives us that integration that tells us we are in the right mode. It tells us we have sustainability of forests for jobs, for communities, and the other resources that depend on it.

It is extremely important in addressing today's complex resource management activities to use satellites for providing meaningful answers to the questions that are raised in management practices and its effect on the environment.

As a resource manager, I feel that the information obtained from satellite imagery gives us an accurate, cost effective assessment of our resources from which we are better able to analyze this information.

It gives us a solid foundation from which we can address current and long term forest resource needs and from which we can develop a long term sustained management plan.

For my testimony I have provided some current overviews which show the integration of this technology. We have gone from a history of base maps that have been available on a two dimensional basis.

These give us the information for contour, streams and roads, but it is important to see the vegetation type. By looking, and the use of the satellites, we are able to look down to a 30 meter area for vegetation.

That gives us a sound foundation from which to determine existing land uses, wildlife uses, and current growing conditions in those stands.

That foundation is used to provide that future look for resources not only on our company lands but the lands within the watersheds that we work. In ecosystem management, it becomes a prime cost effective tool for assessing your operation as well as those that are occurring in the area around you.

Thank you.

Senator BURNS. Thank you, Mr. Thompson. We appreciate you coming this morning.

[The prepared statement of Mr. Thompson follows:]

PREPARED STATEMENT OF MR. TOMMY E.D. THOMPSON

To meet the need for managing and monitoring the diverse forested landscapes owned by Louisiana-Pacific in a timely and cost effective manner, we are utilizing new and sophisticated technologies as tools to do the job. One of these technologies, and one of the best tools is use, is satellite imagery.

The top down, broad landscape views provided by satellite allow us to more accurately describe and quantify the numerous forest stand types we have, as well as evaluate the current (and past) condition(s) of many other forest and watershed resources that are so important to us. L-P also incorporates satellite imagery data into our Geographic Information System. Our GIS. The GIS is another of the powerful analytical tools L-P is using to characterize and map our timberlands.

In addition to data currently in the GIS, such as ownership, roads, topography, streams and watershed data, Louisiana-Pacific Corporation incorporates detailed and sophisticated vegetation inventory data into the system.

Louisiana-Pacific uses computer classified LandSat Thematic Mapper Imagery in conjunction with ancillary data stored in the GIS, such as elevation, slope, aspect and watershed boundaries to inventory its timberlands and to update its timberland inventory. Many ground breaking techniques in forestry applications of satellite imagery were developed to achieve our required level of accuracy. Among these are the use of State of the Art computer hardware and software to integrate as many as sixteen bands of filtered satellite data in the classification process, and a sophisticated two stage sampling design.

Typically 3-5 bands of satellite data are used in vegetation classification. Louisiana-Pacific utilizes 14-16 bands. Using this many bands is necessary to discriminate between certain vegetation types with subtle differences in spectral signatures. Maps displaying the results of classification are composed using Louisiana-Pacific's GIS and returned to local foresters for use in their forest management activities. Training, or ground-truthing, sites for satellite image classification were moved or added for vegetation types that were initially unclassified or mis-classified, and the classification procedure repeated. This process of establishing and adjusting training sites and evaluating results required involved close collaboration between L-P foresters and development staff. The image classification process aggregates contiguous vegetation polygons or stands that can be located and sampled on the ground, then evaluates how near, in terms of species, size and density, the vegetation class of a pixel group is to its neighbors, and appropriately merges small pixel groups with the neighboring, larger group.

This aggregating process is repeated until a minimum stand size (ranging from 1 to 10 acres, depending on management preference for each individual inventory block) is achieved. The assessment of image classification is commonly done by identifying a set of sample locations where the actual vegetation or cover type is known, and then producing tables to show the number of times the image classification procedure correctly and incorrectly called the type.

By integrating satellite image classification procedures with the GIS, Louisiana-Pacific has the capability to develop reports on a wide variety of vegetation and habitat characteristics for its ownership. A framework has been established that allows L-P to periodically update its vegetation coverage and inventory through the further use of satellite imagery. Satellite imagery provides an effective tool for updating information, while maintaining the consistency and integrity of the data, and then integrating it with existing inventory data. The use of satellite imagery greatly reduces the biases of other traditional methods.

Traditional methods of vegetation classification relied on either intensive ground/field plots or aerial photo interpretation and hand mapping. Both of these methods require intensive field efforts and often produce wide variations in accuracy. The utilization of data developed from satellite imagery gives us a consistent, unbiased view of actual vegetation conditions. This is extremely important in addressing today's complex resource management activities and providing meaningful answers to the questions raised in management practices and its effect on the environment.

As a Resource Manager, I feel that the information obtained from satellite imagery gives us an accurate, cost effective assessment of our resources. We are able to better analyze this information. It gives us a solid foundation from which we can address current and long term forest resource needs, and from which we can develop our long term sustained yield forest resources management plans.

[NOTE: Other material submitted for the record will be retained in committee files—Feather Falls Tract Land Cover Classification; Base Data; Spot Orthoimage; Classified Filtered maps; and the Professional Profile.]

Senator BURNS. Dr. Kennel, leading off this morning there was a little article in Aerospace Daily this morning that I probably have to ask you about.

I understand that yesterday the GAO released a study that was critical of a Mission to Plant Earth Program. And you might—the GAO says EOS is unaffordable at $33 billion.

How do you answer your critics regarding this, and what is your reaction to that story, and how does it affect the relevance of this program as it is currently planned?

Dr. KENNEL. Well, thank you for the opportunity to respond so quickly. Actually, we understand why the GAO made its estimate.

What they did is, they took the current cost of the first round of EOS, its satellites that will be launched through the year 2002, and repeated it twice more to get the full program through the year 2022.

So that is where the number of $33 billion comes from. We just hope it gets a realistic number.

If we are implementing this program in 2022 the same way we are in 1998, we have not learned anything. And actually, last year, before all of this started, we started a study using a defense consulting group, the Jasons, and we asked them how would you go about implementing the second round of the Earth Observing System beginning in 2002.

What new technologies can you see coming over the horizon? What should we prepare for?

So, as the concern about long term cost to the government grew very dramatically, our concern to push those studies along also rose.

So when the GAO started this study under Chairman Walker's guidance—actually it was sort of a creative move, because what we have been doing in the last couple of months, two to 3 months, has been to look at the implementation of EOS, the Earth Observing System, in round two and round three.

That is to say, basically, after the year 2000. We are convinced of two things now. We have looked at the first round, the stuff that we will start in 1998 and implement through the year 2002.

We started off in 1991. When we had our first design for the system it was going to cost $17 billion through the year 2000. That might have made the GAO number on the order of $51 billion. But we have looked at the design of that three times now, and we brought the cost down 60 percent in this first round.

We have reached the position, after probing quite a number of times, that the cost of that first round, using present technology, is close to its minimum cost.

You know, we can adjust various budgetary things in a reasonable way, but if significant funds are taken out the first round of EOS, we can say with assurance that the comprehensiveness of the system will be compromised, or that parts of the system will be delayed, or both. We know that there will be a loss now.

That does not mean though that when we go to the second round in the future that we cannot already foresee some things that will bring the cost down. It is sort of like buying a PC.

You know, that they are going to improve 5 years from now, but you have got to do your word processing now, so you go with the best that you can do now, and then you plan for the future. And that is exactly what we have done.

We are looking at new technology and when it will become available in the post–2000 period. NASA has engaged in a specific program called New Millennium to generate new technology for spacecraft so that they will be available in the years after 2000.

We are looking at new operational concepts, working much more closely with NOAA. There is a possibility that a new weather satellite system that—a converged weather satellite system that will start in 2006, or 2004, might be able to do, if we can improve—you know, get the right scientific requirements on it—might be able to do some of the EOS job. We are looking at the development of the commercial market in that time period to see what we can do in partnership there.

All of these steps—we are optimistic that we can bring the cost down maybe a third—the operational cost—in the next decade by these steps if we prepare now.

Then all of these preparations and studies will come together and be reviewed by the National Academy of Sciences. On July 19, the Global Change Program—Chairman Walker requested a review of the Global Change Program. And these studies and the long range evolution of EOS will be finished and reviewed by the scientific community at that time.

Senator BURNS. I was struck by your statement on reliability of all of the data and your ability to collect that data. And then I was struck also with the work, the testimony, of Mr. Bowers and Mr. Thompson on their uses of that data.

And where are we, in your estimation—in your own estimation, where are we in reliability, what we are producing now? Are you happy with the data we are getting with the tools and the equipment that we have now?

Dr. KENNEL. Well, let me use Landsat as an example.

Landsat is, you know, an instrument whose design started 23 years ago, first flight, and has evolved.

And over the years, because we have provided a continuous data stream to a lot of practical users, and they could understand the conditions under which the data was provided, they have been able to develop a lot of very useful applications.

And so it is extremely important to maintain a commitment to the continuous data, to provide the data in a form that the users can understand and work with and develop their own applications.

And it is for this reason that we—that during all of the downsizings, for example, of EOS, we never slipped schedule once.

We want to provide the data on time. It is already in a sense going to be a little dicey with Landsat. We are operating with Landsat–5 at the present time. And as you probably recall, Landsat–6 ended in the ocean.

And Landsat–7, which has come back under NASA control, we are going to launch in May 1998. And we are hoping that five will limp along until we can launch seven. Then, after that the Earth Observing System will take responsibility for Landsat.

And it will fly a second round of Landsat. It will fly Landsat–8 on schedule on the AM–2 spacecraft.

And as I said, we are hoping also to develop some new technology for Landsat users that will be able to produce Landsat-like products and continue that data set, and at the same time provide them with a wider spectrum of actually colors and things to look at that they may also be interested in.

Senator BURNS. I just want to—we will start maybe a little dialog here between Mr. Bowers, who uses your information in making their decisions, as far as managing and putting things together and making sure that the infrastructure exists to operate a city for people to live. In this area, Mr. Bowers, the cost of obtaining that information, is the cost in line?

And maybe I would go back to Dr. Kennel and say, is this an area where maybe—what Dan Goldin has been talking about—is this an area of—an opportunity for privatization?

Mr. Bowers, do you want to comment on what you pay for your information and your cost and——

Mr. BOWERS. Mr. Chairman, perhaps I could make a brief comment, if you would permit me. Our director of advanced technology, Wil Orr is sitting behind me, and perhaps he could make a comment.

It is certainly difficult for us to comment on anything the magnitude of $33 billion, but when it comes down to what we pay now versus what we will pay in the future for the types of data, the quality of data that we will get, and the real time characteristics of the data, we believe that simply in the drainage planning we can save 50 percent with the technology that is pretty much in place today. And also, added to that, with the complexity especially of developing in our sensitive areas around the mountains, that the remote sensing gives us the ability to understand both the ecosystem and the topography of the mountains and the drainage systems within the mountains, and in much more comprehensive fashion, much more cheaply than we can at present by using the imaging capability.

If I might, I would like to ask Wil Orr to comment on that.

Mr. ORR. Thank you, sir. I appreciate the question. Our matrix of applications indicates that for the city of Scottsdale, our order of magnitude of annual savings would be around $5 million.

That is for data acquired both from Mission to Plant Earth and from the Smallsat Program that we see coming on line. We understand that we are dependent on a continuing trajectory of technological accomplishment, however.

But for us, a moderate city of 160,000 people, $5 million a year in data capture is a lot of money. And we do that every year.

And we are doing it just like we did it in 1950, 1960, 1970, and we think there are magnificent technologies we have developed at taxpayer expense that can go back to local governments and really help us do our job far better.

We see the applications for Scottsdale as being very consistent with what will work for Memphis, Dubuque, Sioux Falls and other places. So I think we see a lot of companionship and collateral asset, both between the rural uses and the urban uses.

Thank you, sir.

Senator BURNS. Well, I was interested in your comments this morning. I come from county government. I was a commissioner before I got this job. And I know of what you speak.

And that may be an area to look into--would you like to comment on that, Dr. Kennel? I think maybe this may be an area where we have to maybe take a serious look at what we are doing and the service that we are providing for.

I am wondering how many other metropolitan areas, cities the size of Scottsdale, use this data in their planning process. Do you have any idea or——

Mr. ORR. Sir, everyone—to our knowledge, every other city, small to major, uses the same type of data to operate and manage the city. The question at hand before us today is how we acquire the data.

We are companioned with San Francisco, San Jose, Denver and Portland in the urban consortium. We work with 50 other large cities and counties around the country. And there is extremely strong interest from other cities in sharing the technology with us. We also work with the private sector.

Our intention here is not to be in the space R&D business. We, as a local government, have a high responsibility to our taxpayer.

We are interested in continuing the brief partnership we have with NASA, and then being able to pick up the telephone and call private sector people to get the data, to get the software to process the data and the hardware which we need to run the data.

Senator BURNS. Yes. I have placed you in a customer or a user category. I do not place you in the R&D category. But I place you in a user category, or a customer category. Dr. Kennel?

Dr. KENNEL. Well, the issue of privatization is a very complicated one, but I think if we start with Landsat we have some idea.

I think the experience with Landsat, and also with the French satellites, SPOT, are about consistent, that at the present time, the sale of the images for the variety of practical users is sufficient to support the operations costs of the spacecraft, roughly speaking, but not the original capital investment, which in the case of Landsat–7 will be made by the government.

Now, in the area of land remote sensing, high resolution, with resolution better than 30 meters, there are companies that are betting that at a certain point there will be a self-sustaining commercial market for the spacecraft and the information.

And they are betting on the rapid evolution of three things: faster, better, cheaper spacecraft reducing the net capital costs; great improvements in computing; and probably most significantly the

improvement wrought by the Internet and the creation of a large and sophisticated user community with easy connectivity to the data set.

And all of these things lead a number of people to be optimistic about the development of that market in the future. I, personally, am as well.

And the question, of course, is when is it going to happen—five years from now, 10 years from now? And there are certain imponderables in that it is not here at the present time.

Now, with regard to the other parts of the Earth Observing System, the parts that are devoted to the ocean and to the atmosphere and the parts that are also needed to make an integrated assessment of climate change and predictions in forecasts of the climate, there we are working with newer instruments and instruments, you know, that have not—do not have the 20 year history of development of a user community.

And so it will be some time, I suspect, until they develop their user following. But it would seem to me that with a very large increase in capability like this that if you were to look out ten or fifteen years you would find the development of users of this new and more comprehensive type of data.

We just cannot exactly predict at the present time. If you have ever flown an instrument, you cannot predict exactly what it is going to do.

Senator BURNS. Mr. Thompson, a question for you. I have noticed and observed in your testimony where you are using some of this information. I will assume that Weyerhäuser and Plum Creek and other folks in our same business are using the same data in their management techniques.

Mr. THOMPSON. They are starting to. The technology and application has really grown with the use of computer tools. We are able now to link the data from the satellite to the ground.

And that becomes very critical in the continued use. And that is where we rely on NASA's comprehensive and high quality satellite image that come out now.

Use by other companies is growing. And as was indicated, that becomes a future market. As frameworks are developed that easily integrate the satellite image to land conditions, that will allow us resource managers to recognize the close interrelationship with ecosystem management.

Our harvesting activities, our future land management will shape the future. The satellite gives us that tool.

Senator BURNS. I have often said, you know, that they just have to make—what we are doing at NASA now, especially with this program, is—our first obligation is to this country, is the ability to feed ourselves and the patient use of our water and resources, our land uses.

Dr. Smith is very, very aware of those because of our water use in the west, demands of fresh water. In the 1950's, when I hitchhiked from Missouri to Montana, and I looked at those streams and I looked at the west, and I said, you know, before I die our water will probably be our greatest resource that we have in the west.

And so that is coming to fruition now as population grows because no matter what we do—and I have said it much in this com-

mittee—the second thing we do in this country every morning, everybody, is eat.

I don't know what the first thing you do is. You have a lot of options. But the second thing we do is eat. And we have to be able to make sure that food supply is there.

So, Dr. Smith, do you want to relat to us the data that you use and how it applies to the institution that you are connected with?

Dr. SMITH. We have a remote sensing group in my institute which is part of the Mission to Planet Earth, the Earth Observing System Science Program.

They are working on a number of issues that are important to the program and our region, such things as being able to distinguish between snow and cloud cover.

As you probably know, snow in the mountains is something that we do not do a very good job of measuring. And there is hope that the data from the EOS satellites will give us some help in that area.

Senator BURNS. Right now the only way we are measuring snow pack is—we are sticking them, are we not?

Dr. SMITH. Yes. And, as you know, that is a few points, and there is a lot of variability from place to place. So it is a difficult problem.

There was a cold region workshop just a couple of weeks ago talking about some of these questions. And it is clear that that is going to be an important problem.

Another question in the water budget in our area, of course, is the groundwater. And that maybe has a little longer term perspective, but certainly it is an economically important issue.

Senator BURNS. Thank you very much. Dr. Kennel, in January, 1994 the National Research Council released a review of the EOSDIS system which included that the data management system was too centralized and that the approach being used was risky, inflexible and unresponsive to users. Do you want to respond to those criticisms?

Dr. KENNEL. Yes. The written version of that report was released about two to 3 weeks after there had already been a major design review held with the contractor and NASA Goddard and NASA HQ.

And many of the criticisms that were contained in that report, in fact, nearly all of them, were addressed in this design review.

And NASA Goddard and the contractor sat down and redesigned the system. They made it more distributive, more democratic, if you will, in its architecture, so the data did not flow from one control point.

They designed it in a way that will facilitate its more rapid distribution to a larger variety of users. And my understanding now is that the scientists who act as our surrogates for the larger public at the present time are quite satisfied with that architecture.

Now, at the same time we also understand that the system is going to be used by many more people than scientists. And they designed it, and they designed the instruments. But that data is going to go out on a 24 hour availability basis to a lot of people.

And so this June, right about now—it is very soon—we are going to be having a user conference with practical users of EOSDIS. And

we are going to ask them, well, what sorts of—we are about ready now to deal with this next stage in the design of the system.

And we are going to sit down and ask them, OK, what sorts of features do you need from the system? And we will just evolve the design forward in time.

We have a philosophy that every couple of years we look at the system and we design the next stage. And we, at that time, buy the best commercial software that is possible. And we take advantage of the full development of the outside market.

And we take advantage of our, your know, growing understanding of our user community and their needs and their growing understanding of their needs. So we will just spin the system forward in time.

And it was that design review in December 1993 that enabled this evolutionary approach to the growth of the system.

Senator BURNS. It has been my experience that sometimes scientists, once they gain some information they want to lock it away and say we have got it. Nobody else has got it. We don't want—and kind of sit on it like an egg.

Dr. KENNEL. Yes. Well, that is——

Senator BURNS. And I think the secret to this thing is; is it accessible? And we are talking about new policy on the floor of the Senate—of which I have got to go to here pretty quick—a way in telecommunications of deploying broadband telecommunications that is going to help us distribute.

In other words, super computers, computers, laptops. Who ever thought we would have laptops as one of the most powerful things that we have ever seen anymore?

Again, I am concerned about not only getting the information, the reliability of the information, but then the accessibility.

Dr. KENNEL. Speaking—you know, I came from another branch of space science, actually the oldest branch, Space and Physics. And there, some of my colleagues could be accused of that.

But this is a new subject. These are younger people, relative to me, and they come into this subject already with the knowledge that the data that they are producing for science is important for human decisions and it is important for applications.

And so this group, much more voluntarily as a group of scientists, gives up the data. And they are going to place 224 products on the data stream 24 hours after receipt. Once the system is up and running about 2 years and they have got things right, they are going to just push the data out.

And before that, any user can have access to any of the data. They can go a variety of ways. They can go to Internet. They can call up the EOS Data Center.

They will get whatever we have. It has got to be distributed for the cost of reproduction. And we are going to do that.

Senator BURNS. Well, I think even Mr. Watkins will agree that we are moving into an entirely different era where everybody accesses—immediately we request maps from Geological Survey and they are accessible through our computers to download and to use them immediately almost.

And so I guess that is—and I also have a great love for agriculture and how we make these applications in agriculture, how

our experiment stations are going to use the data that they are using.

Maybe to your surprise, we are finding that now our yields in wheat are starting to level off and go down a little bit for the simple reason that we do not have the people that are really working in developing the disease resistant strains of wheat now that we have had in the past.

So I am concerned that we have to pull all of this together. And it takes people much smarter that I am to do that.

For the last 20 years Landsat has provided the Nation with high quality earth imagery for scientific, government and commercial purposes. To ensure data continuity, it is critical that Landsat–7 be launched in 1998.

What is the status of the dispute between NASA and DoD regarding the $25 million that DoD apparently owes NASA for Landsat-7 but that they have not yet paid the agency?

Dr. KENNEL. Well, this is a very interesting point.

Senator BURNS. Is there a little squabble here?

Dr. KENNEL. Yes, sir. When the transfer of responsibility from DoD and NASA for Landsat–7 was transferred to a management team lead by NASA but consisting of NOAA and USTS, part of the agreement was that the Department of Defense would transfer $90 million that was existing in 1994 funds into NASA's Landsat account.

And there were disagreements of a technical nature over the origin of $24 million of those $90 million. And it had to do with the fact that NASA had transferred some money to the DoD account which then got placed on the contract.

And there was the question of obligation. And obligations occurred by the Department of Defense before the date of the agreement. And these are technical disagreements. But NASA and the Department of Defense disagreed.

In the 1995 budget cycle, the Congress agreed with NASA and directed DoD to transfer $25 million to complete their obligation to the Landsat–7 program. And that $25 million has not been transferred.

Senator BURNS. OK. That is fine. I want to state right now that the users, and of course the providers ear, which is NASA right now, how important your testimony is to this committee.

Senator Pressler, of course, is managing the TELCO Bill on the floor of the U.S. Senate. He wanted to be here this morning. He is highly supportive of this program, as I am, and his statement will be made part of the record.

[The prepared statement of The Chairman follows:]

STATEMENT OF SENATOR PRESSLER

PREPARED STATEMENT OF SENATOR PRESSLER

Mr. Chairman, I want to thank you for holding this oversight hearing on NASA's "Mission to Planet Earth." First of all, let me welcome two South Dakotans to the Subcommittee. *Mr. Al Watkins* is here today representing the U.S. Geological Survey. He is now the head of its National Mapping Division, but he was for many years the director of the EROS Data Center in Sioux Falls. I would also like to welcome *Dr. Paul Smith*. Dr. Smith is the Director of the Institute of Atmospheric Sciences at the South Dakota School of Mines and Technology. Welcome to both of you and to our other witnesses here today.

Mr. Chairman, I believe Mission to Planet Earth is NASA's most relevant program. Mission to Planet Earth will use the latest in satellite technology to help us understand and predict the global climate trends that affect our lives. Mission to Planet Earth is one of the few NASA programs that will yield clear, *direct* benefits to American taxpayers, rather than the speculative "spinoff" benefits promised by other space activities.

In agricultural states like my home state of South Dakota, or livelihood depends on weather and climate. Mission to Planet Earth may some day permit *year-to-year climate prediction* so farmers and ranchers would know in advance whether a particular year would bring floods, droughts, tornadoes, or other severe weather events. The program may also help us determine the location and rate of ozone depletion, which poses a particular threat to our agricultural community.

Beyond its scientific benefits, Mission to Planet Earth may revolutionize the way farmers do business. Mission to Planet Earth will enable a farmer, sitting in front of his personal computer, to access the Internet to obtain soil moisture date on the fields he is cultivating on almost a foot-by-foot basis. For years, the manufacturing industry has applied new technologies to move with more precision. Now it is agriculture's turn. Mission to planet Earth will be a key factor in helping bring this about. Eventually anyone with a computer will be able to obtain detailed data on soil conditions, topography, crops, and other land information. I take great pride in the selection of the EROS Data Center in Sioux Falls, South Dakota, as one of the regional data centers that will help bring "precision farming" and other agricultural applications to the public.

The public, however, will not get the chance to experience this "brave new world" if Congress does not continue full funding for the Mission to Planet Earth program this year. To be sure, this is a particularly tough budget year for NASA. NASA itself already has committed to cut $5 billion in five years from its budget. On top of that, the recent budget plans of the House and Senate call for even deeper cuts. I am concerned that, under these budget constraints, Mission to Planet Earth might be sacrificed to fund Space Station or other NASA programs. That would be a great disservice to America.

Mr. Chairman, I also truly am excited about some of the applications for Mission to Planet Earth data that are being studied by the South Dakota School of Mines and Technology and other schools in South Dakota, Montana, and other Plains States. I am proud of the work they are doing with NASA to develop ways to ensure this satellite data does not sit unused in a data base, but is put to practical use in the community. One of the proposed research projects would focus on the Missouri River Basin. People in South Dakota and Montana who live near the Missouri River fully appreciate the dangers and costs of flooding. Mission to Planet Earth will help provide the tools to understand why such flooding occurs and how to prevent it. I want to commend Dr. Paul Smith from the South Dakota School of Mines and Technology, who is here today, on the fine work he is doing in this area.

Finally, Mr. Chairman, I want to express my concern over the failure of the Administration to resolve an ongoing dispute regarding DoD's failure to transfer to NASA the $25 million it owes that agency for the development of Landsat 7. For the last twenty years, Landsat has provided the nation with an uninterrupted stream of high-quality Earth imagery. As Al Watkins knows, Landsat pioneered many of the remote sending technologies we will talk about today. In our focus on *new* satellite systems, we must take care to preserve *existing* national assets like Landsat. Accordingly, I am eager to hear from NASA about the status of the DoD-NASA funding dispute and about the progress of the Landsat 7 development.

Thank you, Mr. Chairman, and I look forward to hearing from our witnesses.

Senator BURNS. There will be other Senators—because we are really spread thin this morning. We have got everything in the world it seems going on on Tuesday morning. And I know there are questions from other Senators, as I had more to submit.

If we might be allowed to address those questions to you in writing, and if you could respond both to the individual Senators and to this committee, that would be acceptable.

[The information referred above can be referenced in Appendix]

Senator BURNS. And so we appreciate your participation here this morning, especially those folks who use the services that establish the importance of what we are doing in NASA.

And the taxpayer is really getting more for their money than a lot of people read about in the papers or on the front page of The New York Times or The Washington Post.

So we appreciate your participation and coming this morning. So I will leave this committee—I will recess it but not close it. And any other documents that you want to submit for the record, you may do so.

Senator BURNS. And thank you for coming this morning.

We are adjourned.

[Whereupon, at 11:10 a.m., the hearing was adjourned.]

APPENDIX

QUESTIONS ASKED BY SENATOR PRESSLER AND ANSWERS THERETO BY DR. KENNEL

QUESTION 1. Dr. Kennel, would you please detail the status of Landsat 7, which I understand is scheduled for a 1998 launch. Is Landsat 7 on schedule and within budget? Is the Landsat procurement running into any problems?

Answer 1. The Landsat 7 program is progressing well toward a 1998 launch. In his certification letter to the Congress (May 5, 1994), the Administrator established December 1998 as an agency commitment for the launch of Landsat 7. The Landsat 7 development remains within the budget and schedule committed to the Congress. The Enhanced Thematic Mapper Plus (ETM+) instrument, being developed by Hughes/Santa Barbara Research, Santa Barbara, CA, has completed its Critical Design Review (CDR) and is well into manufacture and assembly. The spacecraft, being developed by Lockheed Martin/Valley Forge, PA (previously Martin Marietta), will have its CDR in October 1995, and subsystem reviews are on schedule to meet this review date. The Ground System Preliminary Design Review is on schedule for mid-July 1995. The Martin Marietta contract (spacecraft and instrument) was transferred from DoD to NASA in May 1994 following certification of the program by the Administrator to Congress. The instrument contract was broken-out in June 1994 to be managed directly by NASA (Goddard Space Flight Center, Greenbelt, MD) as a means of cost savings. The Lockheed Martin inception-to-date proposal for the program, from initiation by DoD through transfer to NASA, has been negotiated. The cost-to-complete proposals from Lockheed Martin (spacecraft) and Hughes (instrument) are expected to complete negotiations in July 1995. There are no known procurement problems that would impact the budget or schedule.

QUESTION 2. Landsat 7 started out as a joint NASA/Department of Defense (DoD) program, but last year DoD decided to withdraw from the program. It is my understanding that DoD owes NASA $25 million in FY 1995 funds for Landsat 7, but that money has not been transferred to NASA. Dr. Kennel, would you share with the subcommittee the background and current status of this dispute?

Answer 2. The disagreement between NASA and DoD arises from differing interpretations of the FY 1995 DoD Appropriation, Public Law 103-335 of September 30, 1994. Therein, DoD is directed to transfer $65 million to NASA; $25 million of which is to be used for Landsat 7. In a November 1994 letter to the Chairman of the House Committee on Appropriations from William Perry, the Secretary of Defense, the Secretary stated:

> "I certify that making the transfer of DoD funds to NASA is in the national security interest of the United States."

Subsequently, the funds for Single-Stage-to-Orbit were transferred; however, the funding for Landsat 7 has not been transferred. DoD asserts it has met its requirements to transfer funds to NASA as directed by the Emergency Supplemental Appropriations, Public Law 103-211 of February 12, 1994, which directed DoD to transfer up to $90 million to NASA. A joint NASA/DoD transition plan was signed by the two agencies on February 22 and 24 respectively, recognizing the transfer of the $90 million in compliance with Public Law 103-211. DoD transferred the Martin Marietta (now Lockheed Martin) contract to NASA, having put an additional $45,958,460 (DoD funds) on the contract and transferred $20 million (DoD funds) directly to NASA in July 1994, for a total of $65,958,460. This is just over $24 million short of the $90 million directed. The dispute continues, since DoD believes it has met its obligations; however, the DoD FY 1995 Appropriation, Public Law 103-335, was passed after the transfer of the program (May 1994) and after the transfer of the contract (May 1994), and DoD funds (July 1994) to NASA. NASA interprets this as a directed transfer to recover the shortfall in DoD transfer of funds in FY 1994.

QUESTION 3. Dr. Kennel, the House and Senate budget resolutions both cut NASA's future budgets even more than the Administration's proposed budget. If these cuts were put into place, how would they affect MTPE?

Answer 3. The budget resolutions assume a massive reduction over the next five years to NASA's efforts to study the Earth—Mission to Planet Earth. Such a cut would dismantle the national approach to U.S. global change research priorities established over the last three Administrations and undercut U.S. leadership in this important area of research. It would destroy this program's basic feature—comprehensiveness—and turn an integrated, global program into a series of disconnected and fundamentally less effective measurements. Worse still, it would con-

demn American scientists to pursuing an approach to environmental research which is more than a decade out of date.

The cuts would cripple the core of the program—the Earth Observing System (EOS)—the first integrated satellite and research system designed to observe the linkages among all the components of the Earth system—the land, oceans, atmosphere, ice sheets, and ecosystems. Understanding these linkages is the critical next step to unlocking the secrets of how the environment works and how it affects us all.

NASA's approach to EOS converges both scientific and practical interests. First, the same instruments will collect data of significant value to both communities, as demonstrated by more than two successful decades of Landsat information. Second, scientists recognize that they must be able to translate their research down to the regional level to truly understand global climate effects. Practical users need regional information, as well as its global context. Most importantly, the EOS data will be used to forecast the climate- a year in advance at first, then progressively longer. The ability to make reliable regional and global climate forecasts will have a profound impact on society. Such forecasts are key to major improvements in agricultural and urban planning, water and forest management, investment and capital decisions, and fishing, all of which fundamentally affect U.S. competitiveness. They would also enable improvements in our ability to predict and react to natural disasters, like floods and hurricanes, thereby preventing greater loss of life and property. All of these gains would be lost if the proposed cuts to EOS are sustained.

The U.S. government—in partnership with scientists, private companies, and other nations—must ensure that this cutting-edge research that is the foundation of Mission to Planet Earth is continued. Government leadership in this science and technology innovation is the key to enabling the broad commercial contributions, foreseen by many, in the environmental field and realizing numerous benefits for science, commerce, and policy. NASA has always been at the forefront of such advances in knowledge and we stand committed to this effort.

By walking away from the systematic and comprehensive approach for Mission to Planet Earth, the U.S. would also give up its undisputed world leadership in Earth observations, jeopardize technologies which will be critical to the growing commercial remote sensing market, and reduce our ability to influence the global environmental agenda. Significant U.S. investment in environmental science is the key to preserving this impartiality among nations and sustaining U.S. economic competitiveness in the global marketplace.

NASA is committed to prudent and permanent deficit reduction. Recognizing our fiscal responsibility, NASA has already made enormous reductions in our future budgets. However, further cuts to Mission to Planet Earth—and environmental research in general—seriously jeopardize an investment in the future that will return economic and quality of life benefits far in excess of what we spend today.

QUESTION 4. NASA recently was directed by the Administration to cut its budget by $5 billion over the next five years. How will these cuts affect any of the MTPE activities? If these additional cuts are forced on NASA, how would they affect MTPE?

Answer 4. NASA's Zero Base Review enabled the Agency to identify $5 billion in savings to comply with the President's directive to downsize government spending. These cuts will be taken from the Agency infrastructure and not from the programs. MTPE at Headquarters will be streamlined 40%, from 97 employees to 58 employees. All operational aspects of the program will be transferred to Goddard Space Flight Center, where in-house spacecraft development will be limited and two externally-operated Science Institutes will provide peer review. Goddard will also look for partnership opportunities with NOAA, transfer aircraft operations and management to Dryden Flight Research Center, and work with JPL and the Office of Space Access and Technology to develop advanced technologies for the EOS program.

QUESTION 5. It is no secret some members of the House oppose NASA's Mission to Planet Earth program. Why do you think they oppose it and what is NASA doing to address any legitimate concerns they may have?

Answer 5. While a few members have expressed opposition to MTPE, many others simply do not have a full understanding of the role the program will play and the benefits it will produce. Many have sought additional information, either from colleagues or NASA.

Over the past several years NASA has attempted to strengthen the program through a series of restructurings designed to lower near-term costs while preserving the critical science measurements necessary to understand the global climate.

Now, through NASA initiated studies, we are examining innovative and cost-saving partnerships with industry, interagency, and international partners to further

invigorate the program. We are also actively looking at the long-term aspects of the program with hopes of reducing the post-2000 costs by one third through the infusion of new technologies. We are convinced that MTPE is on the path of reducing a cutting-edge science program at the least cost to the taxpayer.

QUESTION 6. Dr. Kennel, NASA has set budgets for Mission to Planet Earth that grow from $1.3 billion to $1.6 billion over the next five years. Would you say that, once corrected for inflation, NASA's budget profile basically reflects flat funding over that period? Is not Mission to Planet Earth's yearly budget about three quarters of a billion dollars less than that of the Space Station?

Answer 6. When the President's request for MTPE is adjusted for inflation, the budget profile remains essentially flat at $1.3 billion per year from FY 96 through FY 00. When this inflation adjusted budget profile is compared to the capped space station program, the MTPE program averages almost exactly three quarters of a billion dollars per year less than the Space Station program.

QUESTION 7. Dr. Kennel, it is my understanding NASA is committed to further reducing the data management portion of the EOS program. Would you outline for the Subcommittee your plans on how you would accomplish this goal?

Answer 7. NASA's Mission to Planet Earth program will ensure that basic data sets needed for the study of the Earth system are obtained, whether by U.S. government systems, the private sector, or international partners. The data management system for EOS will archive and maintain these data sets on a long-term basis, and make these data sets accessible to the widest possible community of users. The system will facilitate use of the data so as to produce the broadest range of scientific and practical benefits. Finally, NASA believes that the private sector and our international partners may have a larger role in the EOS program, particularly in data management, and we will look for ways to increase their involvement .

The EOS Data Information System (EOSDIS) has been the subject of several internal and external reviews designed to reduce cost and scope. EOSDIS is not being singled out by NASA as a source of savings, but it will continue to be examined along with the rest of the program to see where additional efficiencies and savings might be realized.

Current considerations for streamlining the data management portion of

Mission to Planet Earth include infusing new technology where practical, building on a successful partnership with NOAA to take advantage of interagency cooperation, and evaluating current operations to increase efficiency. We are looking at possible automation of flight operations, consolidation of the network, and streamlining data capture and initial processing. We are also conducting a review of the Distributed Active Archive Centers (DAACs) to see whether there are benefits associated with consolidation of DAAC operations; the study will conclude later this summer. Though many options are under consideration, we want to ensure that any efficiency changes we make do not have a detrimental effect on the accomplishment of our mission goals.

QUESTION 8. Dr. Kennel, the Mission to Planet Earth program has undergone three major restructurings. The cost of the program has gone from about $17 billion to about $7.25 billion—a savings of roughly $10 billion, something I think for which you and NASA deserve credit. Would you comment on the history of these restructurings?

Answer 8. The number of satellites and their data streams have decreased since their inception.

We should be looking at using smaller satellites to reduce costs, flying instruments piggy back on commercial satellites, and purchasing relevant data from the private sector.

NASA has worked extremely hard in collaboration with the scientific community and our international partners to reduce the near-term cost of EOS. The 1991 restructuring, 1992 rescoping, and the 1994 rebaselining each focused on modifying aspects of program implementation while trying to minimize science losses. Clearly, some important science had to be deleted or deferred, and some products and services were scaled back. In doing so, the program moved to a series of smaller platforms, increased the significance of international collaboration, and validated the importance of maintaining the core set of 24 scientific measurements. Finally, through all these exercises, the launch date for the first EOS spacecraft (EOS AM-1) has actually been accelerated; we're on schedule to meet that launch while retaining the most critical science of the mission.

EOS is not static. When first approved in 1990, EOS consisted of 6 large spacecraft. Since that time, the number of spacecraft planned for use in the program has more than quadrupled; this number is likely to go even higher (and the spacecraft get even smaller) as technology makes such sizing reductions and improvements possible. The overall data stream for the EOS program has decreased since 1990,

though the remaining volume of data to be collected and processed is several times larger than what we process in advance of EOS.

The current baseline for MTPE includes a minimum EOS Program that can be accomplished within the new funding restraints, while retaining the basic scientific integrity of the mission. While we have lost some less critical measurements through restructuring, we have continued to maintain our obligations to the U.S. Global Change Research Program (USGCRP).

QUESTION 9. What, if anything, has been lost in these restructurings? Will we still get the same science for our money from the current program?

Answer 9. Restructurings and reductions in funding required that NASA pursue only the highest priority scientific questions in support of national goals, reducing the breadth of observations that were to be collected under the baseline plan of 1990. The new baseline focuses the program on the critical scientific questions on climate.

As mentioned above, some of the less critical measurements and capabilities have been sacrificed to meet the cost restraints of the program. Below is a list of those lost measurements and risks associated with the restructurings.

- Some studies of stratospheric chemistry and characteristics of the mesosphere and thermosphere
- The HIRIS instrument (designed to provide high resolution surface imagery)
- Cancel EOS Color
- Increased risk for science objectives beyond 2000, because of the greater reliance on other agency and international collaboration (with some agreements yet to be negotiated)
- Data continuity risk associated with extending the spacecraft replacement cycle to 6 years from the planned design life of 5 years
- Delays in flight of certain instruments
- Decreased number of at-launch data products
- Descoping of selected instruments

QUESTION 10. Dr. Kennel, what would NASA need to do in order to re-fly the SIR-C radar satellite that flies in the shuttle's cargo bay? It is my understanding NASA and the Defense Mapping Agency (DMA) would like to modify SIR-C and then re-fly it, in order to produce three-dimensional earth imaging and mapping data. What sort of arrangements are NASA and the DMA discussing with respect to a reflight? How soon could SIR-C be reflown once NASA and DoD agree on needed modifications? What, if any, Shuttle launch " slots" has NASA identified for a possible SIR-C reflight?

Answer 10. NASA asked the National Academy of Sciences to evaluate the scientific utility of Synthetic Aperture Radar (SAR), which is the type of radar used on the SIR-C missions and to evaluate the utility of SAR and advise NASA on future strategies for incorporating SAR measurements into the Mission to Planet Earth program.

An interim report from the National Academy of Sciences does not recommend just a repeat flight of the SIR-C/X-SAR radar system. Instead, they recommend that the most useful reflight of this system would be as the Spaceborne Imaging Radar Topography Mission (SIRTM). It is this potential mission plan which we have been discussing with the DMA. Such a mission would produce three-dimensional Earth imaging and mapping data. One possible arrangement under discussion involves NASA modifying the system, conducting the mission and processing the data to the Digital Terrain Elevation Data (DTED) level requested by DoD. In return, the DoD would provide the funding needed to cover the cost of the modifications, operations, processing and any marginal shuttle costs required.

Of course, we would need to find an available slot in the Shuttle manifest for potential flight in the 1997-1998 time frame; while no specific flights are open, we are continuing to work the issue.

QUESTION 11. This year, Canada will launch a satellite that will use radar from space to observe and track ice flows and other ocean phenomena. Other nations, too, have flown space-based radars on free-flying satellite platforms. The United States also has flown space radar payloads, but our efforts seem to have been focused on imaging radars that fly in the Space Shuttle's cargo bay, and therefore must return from space with the Space Shuttle orbiter in which they are installed.

Answer 11. Dr. Kennel, what benefits might the U.S. obtain from developing free-flying space radar satellites? Does NASA have any plans for initiating an operational radar satellite program and, if so, how would it differ from Canada's RadarSat program?

To date, the NASA radar program has focused on using the unique capability of the shuttle to return a payload to Earth after a relatively short flight in space. This has allowed us to significantly evolve our radar technology and design to the current

state represented by the SIR-C/X-SAR system. To try and determine the logical evolution from our current efforts, we asked the National Academy of Sciences to conduct a study to determine the relative utility of radar in Earth observation and to recommend the capabilities that a free-flying system should carry into space. The Academy study will be complete next year.

The capabilities identified and demonstrated by SIR-C are broadly applicable measurements of the geophysical parameters needed to study the Earth as a system (some of which cannot be obtained any other way on a global basis). Perhaps one of the most intriguing is the measurement of topographical changes on the order of inches. The application of this capability to areas of surface change monitoring needed by volcanologists and seismologists is very promising.

In addition, there could be potential benefits to the U.S. private/commercial sector from the measurement of such things as soil moisture, forest composition, tree size and health, the extent of wetlands and the extent of under canopy flooding in the forested basins of the world.

The SIR-C/X-SAR demonstrated the utility of a multi-parameter (multi-frequency, multi-polarization) radar for Earth observation. All currently flying or planned radars are single frequency, single polarization systems which are an excellent sensor for one or two measurement targets. The Canadian RADARSAT which you mention in regard to observing ice and other ocean phenomena is well suited for this task. However, as a single frequency, it will not be capable of measuring many parameters that a multi-frequency system could measure.

QUESTION 12. In 1994, "Version 0" of the Mission to Planet Earth data system—"EOSDIS"—became available, supposedly allowing scientists around the world to work with existing data sets from space observations, and hopefully providing feedback to designers on how the EOSDIS system could evolve and become even more useful. Would you comment on how things are going with EOSDIS Version 0? What sorts of problems are cropping up? Are the users of Version 0 pleased with that system and are they able to make practical use of the satellite data? Is the next stage in the system—Version 1—on schedule?

Answer 12. EOSDIS Version 0 has proven far more successful than NASA could have hoped. Since its release in August, 1994, the number of individual users has grown to 10,000 a month. Version 0 currently offers about 360 data products and expects the number of products to grow to about 400 by the time Version 1 is on line. Some products have been extremely popular and have caused a "surge" in use of as much as 30%. For example, the EROS Data Center released a very popular educational CD ROM of imaging radar from a recent Shuttle mission that nearly doubled the total number of data users in March 1995. Although NASA does not currently track what a user does with his products, the steady rise in data volume delivered indicates that they have increasing utility to the user community.

Feedback from the users indicate that they are satisfied with Version 0. The massive explosion in the use of the Internet has not only expanded the number of Version 0 users, but using Internet has also slowed down the response time it takes to get the information requested. While NASA cannot control the overall response time of the Internet, modifications to Version 0 have accelerated response time for accessing our data descriptions. An unexpectedly large number of users access the data descriptions through the World Wide Web and then call the Version 0 help desk to place an order. As part of our effort to respond to customer needs, we are instituting a World Wide Web "search and order" capability in July 1995 which will likely increase the number of users and the data ordered. Such changes to the data system based on this and other feedback are being incorporated into our flexible design of Version 1, which we plan to release in January 1997—right on schedule.

QUESTION 13. NASA is building two small test satellites—one called "Lewis" and one called "Clark." Is it NASA's position that one of the major missions of these spacecraft is to develop equipment for follow-on Landsat satellites after Landsat-7?

Answer 13. The primary goal of the Small Spacecraft Technology Initiative (SSTI) is technology demonstrations leading to smaller, cheaper, lightweight satellites with greater payload mass fraction for future missions. The SSTI Request for Proposals identified five mission areas of interest to NASA; the industry was required to choose the mission area or areas they would focus on in their proposal. SSTI will demonstrate advanced miniaturization, design and production technology for spacecraft design and instrumentation to greatly reduce the cost of space missions. Technologies will be demonstrated in the power, communication and data handling, attitude determination and control, structure, and mechanisms subsystems and instrumentation. The benefits from the SSTI program will be broadly applied to all NASA space programs. Application of this technology will be applied to Landsat follow-on missions in the broader context of the Earth Observing System. Demonstration of these technologies during the development phase and on-orbit will provide the foun-

dation for incorporation into the EOS program for Landsat follow-on missions in the 2004 time frame. NASA did not design the SSTI to specifically develop equipment for follow-on Landsat satellites after Landsat 7, nor does it believe that the measurements to be made by either Clark or Lewis are a substitute for unique Landsat observations.

QUESTION 14. The "Lewis" and "Clark" satellites are being built under the aegis of NASA's Office of Space Access and Technology, and not MTPE. Are the two NASA offices coordinating with each other in the building and development of these two satellites?

Answer 14. Yes, the two offices are cooperating fully and effectively. MTPE provided support during the proposal evaluation and selection phase and continues to support the Office of Space Access and Technology (OSAT) during the development phase. MTPE will also be directly involved in the operational phase as a member of the experiment tasking oversight group for both Lewis and Clark. Technologies related to spacecraft design are being evaluated by NASA engineers during the development phase to ensure cost effective infusion into future MTPE missions. The science data provided by these developments will be evaluated by the MTPE science team to assess the effective demonstration of Earth science related technologies. MTPE and OSAT are working with both contractors to produce a data policy that will ensure data release as soon as it is verified by the SSTI team and the experimenters. The data will be available through the MTPE data centers, such as the Earth Remote Observation System (EROS) Data Center for the land remote sensing data.

QUESTION 15. Dr. Kennel, what is the overall status of the Mission to Planet Earth program? Is it on schedule and within budget? Over the years, NASA has consistently suffered cost overruns in its programs—on the average of about 70 percent! What steps has NASA taken in the Mission to Planet Earth program in order to insure such overruns do not occur in its activities? Would you discuss these safeguards in detail for this Subcommittee?

Answer 15. The MTPE program is definitely on schedule and we are prepared to implement the program within the funding guidelines proposed in the President's FY 1996 budget. The launch of the first EOS spacecraft, EOS AM-1, has held steady (June 1998) for the last 3 years. Other spacecraft schedules are also holding and many of the instruments are still launching on or near the targets set when the program was originally approved by Congress in 1990.

To reduce the likelihood of cost overruns, MTPE utilizes careful management practices and holds regular program reviews to make sure the program remains on schedule and within budget. The latest rebaselining process enabled us to add back some of the contingency sacrificed in previous streamlining activities. This additional contingency will provide added flexibility when dealing with unforeseen design and development changes.

NASA is presently examining the development of new technology for infusion into the program in the years after 2000. In addition, NASA is examining innovative partnerships with other government agencies and industry to help reduce the future cost of the program. A closer NASA/NOAA alignment and the development of partnerships in a commercial remote sensing market are examples of on-going efforts. By preparing now, these steps will help to drive down the cost of the program in the next decade by as much as one third.

Though there have been difficult scientific sacrifices, NASA has tried to maintain program schedule. NASA has already reduced the EOS budget through the year 2000 by 60% by focusing program on highest priority questions. We are evaluating long-range EOS plan to incorporate technology advances and long-term savings of 30%. We are actively working with users to continue evolution towards a more efficient, practical and cost effective data system. NASA will continue to build upon a successful interagency and international cooperation and collaboration. The practical applications of EOS data will provide increased benefits for state/local governments, farmers, foresters, educators, and others.

Below is a detailed status of the current phase of the EOS program:

The spacecraft and all instruments for the AM-1 mission are currently under contract. All systems remain on schedule for a June 1998 launch.

Award of the Common Spacecraft contract which would provide the satellite bus for the PM-1 and CHEMISTRY-1 (CHEM) missions is planned for September 1995.

With the exception of the Microwave Humidity Sounder (MHS) and Multifrequency Imaging Microwave Radiometer (MIMR), all of the PM-1 instruments are under contract. Since the withdrawal of the European Organization for Exploitation of Meteorological Satellite's (EUMETSAT) offer to provide an MHS instrument, other options have been sought. Currently a variety of arrangements with the Brazilian space agency are being explored. If no satisfactory arrangement can

be made, the instrument will not be flown. Since the European Space Agency (ESA) Council was not able to approve a resolution necessary to provide MIMR for the PM-1 spacecraft, NASA is pursuing National Space Development Agency's (NASDA) offer to provide an Advanced Microwave Scanning Radiometer (AMSR) instrument. Discussions are underway. A US build of a PM Microwave Imager is also being considered as a backup. PM-1 is planned for launch in December 2000.

With the exception of the Ozone Dynamics Ultraviolet Spectrometer (ODUS) instrument, all CHEM-1 instruments are currently in the design/definition phase (Phase B). Japan will submit its ODUS budget request this summer. CHEM-1 is planned for launch in December 2002.

After an extensive study of the Geosat Follow-on (GFO) and TOPEX/Poseidon Follow-on (TPFO) options for the Radar Altimetry mission, the Navy and NASA have agreed to support the TPFO option. Congress has not yet concurred in this decision. Phase B studies continue. Centre Nationale d'Etudes Spatiales (CNES) is pursuing the funding for their portion of a TPFO mission. TPFO could be launched as early as March 1999.

Laser Altimetry Phase A definition studies are underway. Launch is planned for July 2003.

The Active Cavity Radiometer Irridiance Monitor Satellite (ACRIMSAT) approach to flying the ACRIM instrument is being re-evaluated in the light organizational and personnel changes at OSC and JPL respectively.

The Stratospheric Aerosol Gas Experiment (SAGE) instrument is under contract. Arrangements have been made to fly it on a Russian Meteor 3M mission (polar orbit) in August 1998, and on the Space Station (inclined orbit) in February 2001.

The Seawinds instrument is under development. An agreement is being developed with the Japanese Space Agency (NASDA) to fly it on ADEOS-2 in February 1999.

Various opportunities for flying the Solar Stellar Irradiance Comparison Experiment (SOLSTICE) instrument are being explored. The instrument is in the Phase B design/development stage.

The NASA contributions to the Japanese Advanced Earth Observing System-1 (ADEOS-1) mission—the NASA Scatterometer (NSCAT) and a TOMS instrument—have been delivered to Japan for flight in August 1996.

Both the CERES and LIS instruments for the Tropical Rainfall Measuring Mission (TRMM) mission will be delivered to the spacecraft later this year. The planned TRMM launch date is August 1997.

Due to the recent Pegasus XL launch vehicle failure, the launch dates of both the Sea-Viewing Wide Field of View Sensor (SeaWiFS) (data buy) and Total Ozone Mapping Spectrometer (TOMS) Earth Probe missions are uncertain. Both missions could be launched later this year if the Pegasus problems are resolved to NASA's satisfaction.

The TOMS instrument intended to fly on a Russian Meteor 3M mission in August 2000 is scheduled for completion this month.

The Landsat-7 spacecraft is under contract, with the CDR scheduled for later this year. The planned launch date is September 1998.

QUESTION 16. Dr. Kennel, some have suggested that large elements of NASA's Mission to Planet Earth be "privatized." I am a strong supporter of privatizing federal government activities wherever possible, but, given the failure of past efforts to privatize Landsat, would not this be a mistake?

Answer 16. Mission to Planet Earth is first and foremost a science program—the practical applications naturally evolve from the science. Though there is great potential for a value-added applications industry to develop in the future, as of now that industry is still in its infancy. We cannot expect the private sector to invest in pure science, which will not provide them with a short term return on their investment. Our ability to privatize elements of the program would depend upon the ability of external entities to meet EOSDIS requirements, particularly the integration and availability of data.

We are in the process of examining the question of privatization as part of the NASA instituted EOS studies which are in process now. Given the current pace of EOSDIS development, the need to provide timely support to the launch schedules for the initial EOS flight components, and the shifts in the user community anticipated as the data products actually become useful, addressing the issue of privatization before the year 2000 would likely be premature based on our current understanding and on existing and projected market conditions. If NASA were to privatize EOSDIS in the post-2000 time frame, the government would have to insist that the data be preserved indefinitely for future use, the products associated with the instruments must continue to be produced and distributed, and we would have to abide by policies which restrict the cost of selling the data and which provide for non-discriminatory access.

DRAFT
MODIS DATA PRODUCT

POTENTIAL APPLICATION	1	2	3	4	5	6	7	8	9	10	11	12	13
1 - Economic Development/Cone			1		2	1	1	2	1	1	1	1	
2 - Urban/Regional Planning			1		1	1	1	2				1	
3 - Mapping /Charting/Geodesy				1	1	3	2	2				2	
4 - Land Use/Land Cover					2	1	1	3	1				
5 - Agriculture				2	3	2	2	3	3				1
6 - Forestry				1	3	1	1	3	3				
7 - Rangeland					3	1	1	3	3				
8 - Emergency Management				1		2	3	1					1
9 - Transportation						2		1					1
10 - Exploration/Extractive					1		3	2	1				
11 - Weather/Climate	1	2	2	2	1	3	3	1		1		3	2
12 - Air Quality		2	3	1			2						1
13 - Water Quality		2			1		1	1	2	1	1	1	
14 - Water Resources		2			2	3	1	2	1	1			
15 - Fisheries				1		1		1	3	3	2	3	2
16 - Marine	1	2							1	2	1	3	1
17 - Recreation				1		2			1	1		1	1
18 - Intelligence	1	2			3	3	3	1	1	2	1	2	2
APPLICATION CATEGORIES	3	6	4	8	12	14	14	14	12	8	5	9	9
AVERAGE APPLICATIONS	1	2	1.7	1.2	1.9	1.8	1.8	1.9	1.7	1.4	1.2	1.9	1.3

MODIS DATA PRODUCTS
POTENTIAL COMMERCIAL
APPLICATIONS

APPLICATION KEY
1 - Some Possible Use
2 - Moderate Use
3 - High Use
Blank - None Expected

MODIS DATA PRODUCTS

1 Level-1 A Radiance
2 Level-1 B Radiance Calibrated, Geolocated
3 Aerosol Product
4 Cloud Product
5 Surface Reflectance
6 Snow Cover
7 Land Surface Temperature/Emissivity
8 Land Cover Type
9 Chlorophyll_a Pigment Concentration
10 Water-leaving Radiance
11 PAR
12 Sea Surface Temperature
13 Could Mask

DRAFT

LANDSAT ETM+ DATA PRODUCTS - POTENTIAL COMMERCIAL APPLICATIONS

APPLICATION KEY
1 - Some Possible Use
2 - Moderate Use
3 - High Use
Blank - None Expected

	ETM+ DATA PRODUCT		
POTENTIAL APPLICATION	15M PAN	30M SPEC	60M THERM
1 - Economic Development/Cone	2	2	1
2 - Urban/Regional Planning	3	2	2
3 - Mapping /Charting/Geodesy	2	2	1
4 - Land Use/Land Cover	2	3	1
5 - Agriculture	2	3	2
6 - Forestry	2	3	1
7 - Rangeland	2	2	1
8 - Emergency Management	1	2	2
9 - Transportation	2	1	
10 - Exploration/Extractive	2	3	2
11 - Weather/Climate			
12 - Air Quality			
13 - Water Quality		2	1
14 - Water Resources	1	3	1
15 - Fisheries		2	1
16 - Marine		1	1
17 - Recreation	2	2	
18 - Intelligence	3	3	3
APPLICATION CATEGORIES	13	16	14
AVERAGE APPLICATIONS	2	2.25	1.4

DRAFT

ASTER DATA PRODUCTS - POTENTIAL COMMERCIAL APPLICATIONS

ASTER DATA PRODUCT

POTENTIAL APPLICATION	1	2	3	4	5	6	7	8	9
1 - Economic Development/Cone				1	2	1	1	1	2
2 - Urban/Regional Planning				1	3	2	2	3	3
3 - Mapping/Charting/Geodesy				1	2	1	1	1	3
4 - Land Use/Land Cover					3	2	1	2	2
5 - Agriculture				2	3	2	2	2	1
6 - Forestry				1	3	1	1	1	2
7 - Rangeland				1	2	1	1	1	2
8 - Emergency Management				2	1			1	2
9 - Transportation					1				2
10 - Exploration/Extractive				1	3	2	3	3	2
11 - Weather/Climate		1		2				1	2
12 - Air Quality		1		1	1				
13 - Water Quality		1		1	1		1	1	
14 - Water Resources				1	2	1	1	1	1
15 - Fisheries		1		2	1			2	
16 - Marine		1		2	1			2	
17 - Recreation					1			1	1
18 - Intelligence		1		1	3	2	2	2	3
APPLICATION CATEGORIES	0	6	0	15	17	10	11	16	14
AVERAGE APPLICABILITY		1	0	1.3	1.9	1.5	1.4	1.6	2

1 - Some Possible Use
2 - Moderate Use
3 - High Use
Blank - None Expected

Aster Data Products

1 Reconstructed Unprocessed Instrument Data
2 Registered Radiance at Sensor
3 Decorrelation Stretch
4 Brightness Temperature
5 Surface Refelctance
6 Surface Radiance
7 Surface Emissdivity
8 Surface Kinetic Temperature
9 Digital Elevation Model

APPLICATION KEY

QUESTIONS ASKED BY SENATOR BURNS AND ANSWERS THERETO BY DR. KENNEL

BUDGET

QUESTION 1. What is the FY 1996 budget request for MTPE and what activities would it support? Projected outyear costs of the program?

Answer 1. The overall goal and mission of the Mission to Planet Earth (MTPE) Enterprise is to understand the Earth as an integrated system and to measure and discern causes for (and eventually predict) changes in the global environment. The vantage point of space provides unique global information about the Earth's land, atmosphere, ice, oceans, and life that is obtainable in no other way. The MTPE's Earth Observing System (EOS) will establish the foundation for a new, innovative approach to global environmental monitoring and climate prediction.

The FY 1996 President's Budget request for MTPE in total is $1,341.1 billion. This budget will fund the following: continued development of satellite, instrument and ground systems as part of the Earth Observing System (EOS), release Version 1 for EOSDIS, payload and instrument development in addition to EOS, Mission to Planet Earth science and applications, development of curriculum materials and evaluation of GLOBE pilot program, completion of the Earth Systems Science Building at Goddard Space Flight Center, and launch vehicle support.

Upcoming activities for FY 1996 in the MTPE program include, in the Earth probes program, launch of the first Total Ozone Mapping Spectrometer (TOMS) Earth Probe, the NASA Scatterometer and TOMS on the Japanese Advanced Earth Observing System (ADEOS) spacecraft, and the Ocean Color Mission (SeaWiFS). The mission operations and data analysis program within MTPE will begin operations of the Earth Probes satellites and processing of the data received from them, in addition to maintaining activities for currently orbiting spacecraft and recently completed space shuttle missions. The instrument and payloads development program will be focused on Shuttle-Imaging Radar-C (SIR-C) and Atmospheric Laboratory for Applications and Science (ATLAS-3) post-mission activities. Critical design reviews will be held within the Earth Observing System. The EOSDIS will release Version 1 and prepare for the release of Version 2.

Outyear costs of the program as planned in the FY 1996 President's Budget are as follows:

FY 1997	FY 1998	FY 1999	FY 2000
$1,379.4	$1,483.0	$1,498.1	$1,580.8

For the post-2000 costs, the program is assessing alternative ways to acquire necessary science measurements at a reduced cost, through the incorporation of advanced technology and increased use of innovative partnerships; initial indications are that we could achieve up to a 30% reduction in the long term cost of the program.

QUESTION 2. How will MTPE be affected by NASA's plan to cut $5 billion in five years from the agency's budget?

Answer 2. NASA's Zero Base Review enabled the Agency to identify $5 billion in savings over 5 years to comply with the President's directive to downsize government spending. These cuts will be taken from the Agency infrastructure and not from the programs. MTPE at Headquarters will be streamlined 40%, from 97 employees to 58 employees. All operational aspects of the program will be transferred to Goddard Space Flight Center, where in-house spacecraft development will be limited. Goddard will also look for partnership opportunities with NOAA, transfer aircraft operations and management to Dryden Flight Research Center, and work with JPL and the Office of Space Access and Technology to develop advanced technologies for the EOS program.

QUESTION 3. Both the Senate and House budget plans are based on assumptions of another billion dollars in cuts at NASA. Can Mission to Planet Earth survive that additional budget pressure?

Answer 3. The budget resolutions assume a massive reduction over the next five years to NASA's efforts to study the Earth—Mission to Planet Earth. Such a cut would dismantle the national approach to U.S. global change research priorities es-

tablished over the last three Administrations and undercut U.S. leadership in this important area of research. It would destroy this program's basic feature—comprehensiveness—and turn an integrated, global program into a series of disconnected and fundamentally less effective measurements. Worse still, it would condemn American scientists to pursuing an approach to environmental research which is more than a decade out of date.

The cuts would cripple the core of the program—the Earth Observing System (EOS)—the first integrated satellite and research system designed to observe the linkages among all the components of the Earth system—the land, oceans, atmosphere, ice sheets, and ecosystems. Understanding these linkages is the critical next step to unlocking the secrets of how the environment works and how it affects us all.

NASA's approach to EOS converges both scientific and practical interests. First, the same instruments will collect data of significant value to both communities, as demonstrated by more than two successful decades of Landsat information. Second, scientists recognize that they must be able to translate their research down to the regional level to truly understand global climate effects. Practical users need regional information, as well as its global context. Most importantly, the EOS data will help to forecast the climate—a year in advance at first, then progressively longer. The ability to make reliable regional and global climate forecasts will have a profound impact on society. Such forecasts are key to major improvements in agricultural and urban planning, water and forest management, investment and capital decisions, and fishing, all of which fundamentally affect U.S. competitiveness. They would also enable improvements in our ability to predict and react to natural disasters, like floods and hurricanes, thereby preventing greater loss of life and property. All of these gains would be lost if the proposed cuts to EOS are sustained.

The U.S. government—in partnership with scientists, private companies, and other nations—must ensure that this cutting-edge research that is the foundation of Mission to Planet Earth is continued. Government leadership in this science and technology innovation is the key to enabling the broad commercial contributions, foreseen by many, in the environmental field and realizing numerous benefits for science, commerce, and policy. NASA has always been at the forefront of such advances in knowledge and we stand committed to this effort.

By walking away from the systematic and comprehensive approach for Mission to Planet Earth, the U.S. would also give up its undisputed world leadership in Earth observations, jeopardize technologies which will be critical to the growing commercial remote sensing market, and reduce our ability to influence the global environmental agenda. Significant U.S. investment in environmental science is the key to preserving this impartiality among nations and sustaining U.S. economic competitiveness in the global marketplace.

NASA is committed to prudent and permanent deficit reduction. Recognizing our fiscal responsibility, NASA has already made enormous reductions in our future budgets. However, further cuts to Mission to Planet Earth—and environmental research in general—seriously jeopardize an investment in the future that will return economic and quality of life benefits far in excess of what we spend today.

QUESTION 4. Critics of Mission to Planet Earth in the House of Representatives have proposed that your program be cut by $2.7 billion and that the bulk of the cut be applied to the data management activities.

- If a large budget reduction is applied to the data management part of Mission to Planet Earth, what effect would that have on NASA's ability to process the satellite data and distribute the data to the public?

- What kinds of credible changes in the program could be made to obtain that level of cost savings, yet still support good science?

Answer 4.

• First, as noted in the previous question, the magnitude of the reductions would be extremely damaging to Mission to Planet Earth. The program could not sustain a cut of that magnitude without losing major objectives.

• Second, even if we were inclined to take all the reductions out of EOSDIS, we would still need to make substantial cuts to the science and observations portions of Mission to Planet Earth.

• Third, large cuts to EOSDIS would severely hamper our ability to support scientific analysis of EOS data and to make that data readily available for the many others who would use it, thus potentially negating or delaying many of the significant benefits noted above.

Reviews and Studies of the Program

QUESTION 5. I understand that the House Science Committee, which has been critical of Mission to Planet Earth, has commissioned a new set of studies of the program by NASA, as well as the National Academy of Sciences.

a. What issues will be addressed by the NASA and Academy studies address and when will the studies be completed?

Answer 5a. Mission to Planet Earth has undertaken a number of activities that will help us chart the most logical course for implementing our program in the future. First, consistent with a request from Chairman Walker, we initiated a study in late March to examine the long term implementation of Mission to Planet Earth, with a focus on the incorporation of emerging technology and capabilities. We are examining science, data, and flight program requirements and opportunities beyond the turn of the century to help us more effectively take advantage of technological evolution and increased partnerships. By incorporating new technologies into the program—while maintaining critical measurement continuity—we are confident that we will be able to reduce the long term cost of the program (in particular that of the Earth Observing System) while making the system both more resilient and capable. Second, we are undertaking a series of studies with NOAA to define the means by which the two agencies could better coordinate and cooperate to accomplish mutual objectives, with a focus on technology infusion, program synergy, and data systems.

Mission to Planet Earth has been working over the summer to update its science implementation plan, both to reflect progress made in Earth system science in recent years, and to further integrate EOS science with the research and analysis program. This plan identifies four science priorities for the next five years. These are: Atmospheric ozone, Seasonal-to-Interannual Climate Prediction, Long-term Climate Variability, and Land Cover Change and Global Productivity. A research strategy for each area is under development as part of the overall plan. These basic research priorities are consistent with those of the interagency U.S. Global Change Research Program, and will result in new knowledge of practical benefit to agriculture and other economically important endeavors.

These studies reported their findings and status to the NRC Board on Sustainable Development in mid-July. In his original letter to the Academy, Chairman Robert Walker of the House Science Committee asked the Board to examine the implementation of the U.S. Global Change Research Program and also to review NASA's responses to issues which he asked us to address. The NRC review is being co-chaired by Dr. Edward Frieman of Scripps and Dr. Berrien Moore from the University of New Hampshire. We will assess the guidance and suggestions from the Board review when formulating the baseline program plan that we will use to prepare the FY 1997 NASA budget.

b. How many internal and external reviews has Mission to Planet Earth undergone since it was started and do you expect the latest round of studies to provide any new insights?

Answer 5b. Since the new start for EOS was approved in 1991, the program has undergone major review three times, the net result of these efforts was to reduce program cost through 2000 from $17 billion to $7.25 billion, while preserving the most critical measurements shifting the program to the use of smaller spacecraft and reliance on increased international cooperation. When EOSDIS was externally reviewed by the National Research Council in 1993, they generated a number of constructive recommendations, virtually all of which were incorporated into the program. In addition, the National Research Council has produced several reports which address EOS implementation, as have the Office of Technology Assessment and the General Accounting Office.

For EOS, we are committed to a long term data set with instruments flown multiple times to enable us to discern the signature of climate change and to understand its processes. The baseline program involves the flight of 24 different measurements for at least 15 years of continuous EOS measurements for studying air, water, land and life from the unique vantage point of space. Thus the main issues of interest to NASA addressed during the workshop (and likely in the subsequent report) will be those relating to the science planning for Mission to Planet Earth and EOS, the evolution of measurement and ground systems, and the prospects for greater synergy in meeting program objectives, both with other federal agencies and our international partners. While we anticipate that the instruments and the spacecraft groupings will evolve over time, we must acquire the measurement "types" included in the program and do so continuously for 15 years. The accuracy and precision of these measurements must also meet baseline science and mission requirements.

We believe that the current study efforts will help chart the course for the program in the next century. The MTPE Evolution Study will develop a cohesive, integrated technology development plan to infuse new technology more aggressively in order to maintain basic MTPE scientific objectives, and to find more economical and flexible ways to implement future MTPE measurement and data systems.

The NASA/NOAA Alignment activity was instituted to identify cost savings and service enhancements which could emerge from a closer integration of NASA's and NOAA's environmental observation and research programs. A roundtable was set up between NASA and NOAA senior officials which will meet regularly to examine the results of three working groups: collocation synergy, which will explore new approaches to research/operations by taking advantage of collocation; technology infusion, designed to explore new/innovative ways to incorporate advanced technology from MTPE into NOAA's environmental weather satellite system; and, data systems synergy, which will develop innovative ways of using NASA and NOAA data systems to solve mutual problems more effectively.

A third study effort will develop the MTPE Science Plan which will respond to research issues identified by National Academy of Sciences/ National Research Council, the World Climate Research Programme (WCRP), and the Intergovernmental Panel on Climate Change (IPCC). This science plan will identify roles which are uniquely NASA's and set priorities to integrate EOS interdisciplinary science with MTPE Research and Analysis program. The study will provide "roadmaps" for identifying necessary interagency and international collaborations. The plan will be reviewed by the NRC Board on Sustainable Development this summer, with completion expected by this fall.

QUESTION 6. At our March oversight hearing on the NASA budget, Administrator Goldin indicated NASA was conducting a review of all of the data centers for Mission to Planet Earth, with the view towards eliminating one or more. What is the status of that review and what criteria are being used to evaluate the individual centers?

Answer 6. NASA has commissioned an external review of all Distributed Active Archive Centers (DAACs) to examine this question. Results are anticipated to be available by late summer. At present, all DAACs have roles and responsibilities which are believed to be important to the success of MTPE. The review will address whether these functions could be more efficiently executed by fewer DAACs and/or in combination with other data centers without compromising the quality of user service.

NASA is committed to efficiency in operations by refining a plan for the DAACs which preserves the essential goals of this innovative data and information system. The results of this review will offer us the opportunity to fully examine a host of alternatives and then select the optimal DAAC development plan.

Scientific Benefits of the Program

QUESTION 7. One of the main criticisms of the Mission to Planet Earth program is that it is focused on the wrong scientific questions and that it overemphasizes global warming research.

a. In lay terms, what are the chief scientific questions that Mission to Planet Earth is expected to answer and why are they important to the average citizen?

Answer 7a. The basic scientific goal of MTPE is to understand the Earth as an integrated system of land, water, air and life. Science objectives address the fundamental physical, chemical, and biological events that govern and couple the Earth's climate. While a better understanding of potential increases in global temperature is one possible product of such research, there are many other scientific and practical insights which will also be generated. By focusing the program on solid science—the most critical questions needed to better understand the complex interactions of the global climate—we can generate maximum benefit. Important scientific questions include. How do El Niño and other climate patterns affect our weather? Are there long term weather patterns that are changing and how might those changes affect sea levels and global temperature? Will sea levels rise? Will the Earth get warmer? Is the ozone layer still in danger? Results of MTPE science will help to answer critical questions about climate change on a global and regional scale. MTPE science will also help to minimize hazards to human life and property from natural events such as earthquakes, volcanic eruptions, severe storms, and floods. MTPE science will yield improved weather forecasts, tools for managing agriculture and forests, information for fisherman, tools for coastal planners, and eventually, the ability to predict how the climate will change in the future. All of these are important to our economic competitiveness and well being, as well as to our overall quality of life.

b. To many, Mission to Planet Earth is mainly concerned with studying whether human activities such as auto emissions and industrial pollution are causing global warming. Is that a fair characterization of the program's central focus?

Answer 7b. No. As noted above, the program is focused on the integrated understanding of the global climate. While this understanding will give us insight into the potential effects of such emissions on global temperature, such insight is but one of the many outputs of the program.

QUESTION 8. Mission to Planet Earth is designed to look at the sea, atmosphere, land, and ice caps as an integrated system. How does this approach differ from our current way of looking at climate change?

Answer 8. In the past, the study of climate change was approached by disconnected scientific disciplines making often independent measurements. While these efforts did much to advance our understanding of the climate, the need to understand the linkages is key to making future breakthroughs. MTPE is the first integrated system designed to study the interactions between land, water, atmosphere, and life—studying these interactions on a global and regional basis will give us a comprehensive understanding of climate change. It brings together many fields of scientific study, such as meteorology, oceanography, biology, and atmospheric sciences. Through EOS, MTPE will provide systematic, continuous observations for a minimum of 15 years of those measurement areas critical to understanding climate change. By simultaneously monitoring different elements of the Earth over time, we will be better able to understand the dynamic nature of the Earth and make forecasts of the climate a year or more in advance.

Space-based monitoring alone is not sufficient. A comprehensive data and information system, a community of research scientists, and extensive ground and airborne efforts are also needed. More than any other factor, the commitment to make Earth science data easily accessible to all users and researchers is critical to MTPE's success; the ability of these researchers and other users to effectively see how data "fits together" will be one of the most important aspects of the program.

QUESTION 9. We hear a lot about El Niño—the climate disturbance that occurs every three to five years and causes dramatic changes in rainfall and wind patterns around the world. How will Mission to Planet Earth advance our understanding of El Niño and similar climate phenomena?

Answer 9. Through remote sensing and other measurements, we already know a great deal about El Niño events. We know its a fairly regular climate disturbance caused by the eastward movement of warm water across the Pacific. In doing so, it alters weather and rainfall patterns, wind directions and even the jet stream, in both the tropics and the northern hemisphere. Though scientists do not fully understand why it forms, they do believe that the El Niño conditions may have contributed to the 1993 Mississippi and 1995 California floods and caused drought as far away as Australia and Africa.

Only with global measurements can scientists trace the formation of El Niño, precisely track its movement, and monitor its effects. As measurements improve over the coming years, researchers will be able to predict these events and their consequences more than a year in advance, giving farmers, landowners, and others a chance to plan accordingly. In 1999, as part of EOS, we will try another altimetry satellite (EOS-ALT) to continue data collection needed to monitor and better understand El Niño events.

QUESTION 10. For the farming and ranching communities in particular, ozone depletion is a serious matter. Not only does ozone depletion pose health risks to those of us who work outdoors, but it also can harm livestock and cause crop damage. What information will the program provide us on the location and rate of our ozone depletion and what can be done about it.

QUESTION 11. By international agreement, all of the industrialized nations have agreed to stop production of CFCs (which cause ozone depletion) by 1996. Will this action reverse the damage to the ozone layer that has already been done?

Answer 10 & 11. MTPE will continue to research and monitor the location and rate of ozone depletion. Later in 1995, NASA plans to launch the Total Ozone Mapping Spectrometer (TOMS) instrument on a NASA Earth probe satellite. Phase I of MTPE includes additional flights of TOMS instruments on the Japanese ADEOS spacecraft and Russian Meteor-3 spacecraft in 1996 and 2000, respectively. These instruments provide global ozone concentration data on the Earth's upper and lower atmosphere and will continue to monitor the heightened ozone depletion in the Antarctic.

While ozone levels over Antarctica and the rest of the globe will continue to decline for several years, NASA and NOAA measurements have now detected evidence that the international treaties to protect the ozone layer are beginning to work. Concentrations of ozone-depleting chemicals are beginning to level off. Continued efforts

by MTPE to monitor ozone levels are needed to understand how CFC substitutes are affecting ozone levels. The degree to which the damage to the protective ozone layer can be reversed will only become clear as we continue to monitor the situation.

QUESTION 12. In 1998, the first of the Earth Observing System (EOS) satellites—EOS AM—will be launched. What instruments will EOS AM carry and what aspects of global climate will it focus on? What are some of the other climate measurements that will be taken by the follow-on EOS satellites?

Answer 12. The EOS-AM-1 observations will address key issues in atmospheric, land, and ocean sciences. The EOS-AM instruments will provide critical data on clouds and radiation fields. These observations, when combined with the equivalent data from EOS-PM, will provide insights into the role of clouds in the physical climate system. The EOS-AM-1 and Landsat measurements will address key issues in land atmospheric, and ocean sciences. Climate processes are the focus of the EOS-PM-1 measurements, though other missions will also make important contributions. Atmospheric chemistry studies will include a number of measurements, including those from instruments on the EOS Chemistry spacecraft as well as SOLSTICE, SAGE, and MOPPITT. Ocean processes, which play a central role in the climate system, will be the focus of measurements both by EOS and other instruments and spacecraft. These measurements, and those made by other agencies and nations, are new in their comprehensiveness, precision, and volume, and ought to advance our scientific understanding significantly.

EOS-AM-1 is composed of five instruments: CERES, MODIS, ASTER, MOPPITT, and MISR. CERES will focus on the role of clouds as one of the largest sources of uncertainty in the understanding of global climate change. MODIS will provide precise observations of cloud cover, sea and land surface temperatures, and changes in the land. MISR will provides multidirectional, continuous Earth observations at a high level of clarity. ASTER will provide high resolution images of the land surface, water, ice, and clouds and MOPPITT will provide data to better understand how human activities effect CO and CH4 levels in the atmosphere.

As with all EOS measurements, they provide an essential puzzle piece in our efforts to understand changes in the climate on a global scale. The follow-on EOS instruments will focus on how the land, water, atmosphere, and life interact with one another. This approach, called Earth system science—blends together fields like meteorology, oceanography, biology, and atmospheric science. Each EOS satellite will provide science information on distinct interactions of the land, atmosphere, water and life that will ultimately touch different segments of society—the global understanding will yield local and regional benefits. A sampling of those we can predict with confidence includes:

1. EOS-AM satellite data will focus on surface and cloud processes and will provide precise land images for farmers, businesses, state/local governments
2. EOS-PM measurements will enable fundamental improvements in climate and weather forecasting, thus giving farmers and others a powerful tool for managing what they plant and when
3. In combination, EOS-AM and EOS-PM will enable precise measurements of ocean plant productivity, an important tool for tracking fish concentrations
4. EOS-CHEMISTRY observations will focus on the complex atmospheric interactions and will greatly improve monitoring of air pollution and ozone levels
5. EOS-ALTIMETRY (RADAR) data will enable us to make precise sea level measurements and determine whether ocean levels are rising, a subject of considerable interest to the 50% of the U.S. population living within 50 miles of a coastline. This mission will also help track and forecast El Niño events
6. EOS-ALTIMETRY (LASER) readings will accurately measure polar ice sheets and their effect on global climate and sea levels
7. The combination of EOS-AM-1 and LANDSAT-7 will advance our understanding of how vegetated land surface interacts with the atmosphere in controlling energy, water and carbon fluxes.

This research provides the knowledge necessary to understand the dynamics of our planet. As with all scientific endeavors, Mission to Planet Earth will likely provide some surprising results which will lead to a more advanced knowledge of our world.

QUESTION 13. Many are concerned that Mission to Planet Earth will generate mountains of valuable satellite data, but everyday people will not have meaningful access to that information. Let us say a farmer wants satellite data on the soil composition and water content of his farmland. How would that farmer get useful, relevant, and understandable information from the program? Would you explain what steps he would have to go through from beginning to end, step-by-step?

Answer 13. Through the observations gained from our satellites and other platforms, Mission to Planet Earth provides the critical first step: raw data collection.

We will also have access to data from satellites and instruments flown by our international partners. The data then becomes accessible to scientists and others through nine Internet-accessible data centers across the country. At that point, the ability of an individual to use the data would depend on a number of factors, including the type of information sought (single or multiple data sets), the level of integration and analysis required, the skill of the user, and complexity of the problem or issue. For some non-science users, it is likely that they will find greatest value in information which has been molded into a practical and marketable format by the application. For example, a Midwestern applications firm could specialize in creating marketable agricultural data products which would provide farmers with the specialized information they need for precision farming. The farmer would contact the applications firm and contract for the particular information that he desires at an agreed upon price.

With the raw data supplied by EOS measurements over the coming years, the opportunity exists for a value-added industry to flourish. Landsat provides an example of how this data can be transformed from science data to marketable products for state/local governments, farmers, foresters, educators, and many others. Though we cannot predict with certainty the size and scope of the economic benefits of the program, we believe that the data provides the possibility for a number of marketable products for a number of users.

LANDSAT

QUESTION 14. Much of the focus on new satellites is understandable, but what is MTPE doing to make better use of existing remote sensing assets like Landsat? What are the main civilian uses of Landsat data today and what role will Landsat play once the larger EOS satellites are launched beginning in 1998?

Answer 14. Landsat data are used primarily by the civilian community for land cover monitoring and assessment, and research on a variety of terrestrial processes. The data are used for this purpose by researchers and educators, civil agencies at all levels (federal, state and local), by non-government organizations, and commercial operators. Landsat data are uniquely suited for land cover monitoring and assessment. Applications in forest management, wheat yield, fisheries and water resource development, earthquake and flood damage assessments, ecological, glaciological, hydrologic, and agricultural research, and geological explorations are a few examples of the uses of Landsat data.

NASA has already stimulated the additional use of Landsat data through its Landsat Pathfinder Program, and through a series of research grants for applications. In addition, data on deforestation around the world is currently being collected, with a goal of producing a global estimate of tropical deforestation within the next two years, and of making all the underlying data available for non-commercial uses. Applications research grants have investigated the use of Landsat data for specific management applications, such as monitoring the impact of wetlands loss or predicting crop yield more accurately. It is our view that such programs will lead to greater use of Landsat data in the research, educational, and civil agency communities, and that this increase in the overall user base will also eventually be translated into greater opportunities for commercial use.

No other single satellite system now in operation offers the combination of spatial resolution, spectral coverage and extent of coverage as Landsat. The TM spectral bands cover four regions of the spectrum: visible, near infrared, middle infrared, and thermal infrared. Each region provides independent information on major land surface features. The bands were carefully placed within each region to maximize sensitivity to the state of the land surface while avoiding major atmospheric absorption bands. The coverage of the middle infrared remains unique; no other orbiting sensor covers this region.

The TM also offers a spatial resolution essential to monitoring global change and land surface states. Many surface level changes, including deforestation, can only be resolved at spatial resolutions offered by the Landsat TM and SPOT. Of the two, only the Landsat data record is long enough, sufficiently well-understood, and of wide enough geographic coverage to be broadly useful for global change research. The wide-area coverage of TM and its repetitive, synoptic nature are of critical importance to establishing a baseline that can differentiate between the natural variability of land surface features and changes that are human-induced.

Finally, the full utilization of the Landsat data record for land surface monitoring requires absolute radiometric calibration of the data. Monitoring the land surface requires the comparison of data sets, both from previous Landsats, but also from other current and planned satellite systems (e.g.SPOT and EOS). Without calibra-

tion, discerning differences due to land surface change from differences due to sensor response may be difficult, if not impossible.

An additional advantage of Landsat data is the length of the record of acquisitions. No other land satellite system provides the longevity of Landsat. Landsat data have been collected since 1972. In general, the archive of Landsat data is as important as any of the sensors' spectral, radiometric or geometric capabilities. Because Landsat was conceived primarily as a monitoring system, and has been operated in a survey mode for the entire duration of the program (through Landsat 5), the completeness of the archive both spatially (with near-global coverage) and temporally (approximately 20 uninterrupted years of data) is without parallel in Earth system science. Programs like EOS, part of whose scientific rationale depends on being able to detect changes in surface cover and surface processes, depend on the existence of an archive of sufficient length and spatial coverage to establish a baseline from which deviations can meaningfully be measured. Indeed, for many processes that affect surface cover, a twenty-year archive is barely sufficient to establish a reasonable baseline that incorporates natural variability, and against which changes can be measured. It is imperative from a scientific perspective that the archive be extended in both length and possibly in spatial coverage, so as to provide a truly global baseline.

Because of the importance of the archive, continuity will remain the most important and challenging aspect of the Landsat program. Planning for Landsat follow-on must, at a minimum, provide for both continuation of the scientifically essential aspects of the data stream and sensor performance, while permitting technological improvements in sensor capability. As Landsat returns to government control with the development of Landsat-7, it becomes important to consider how it relates to other sensors and systems operating now, and planned for the near future. The primary survey mission of Landsat is similar to that of the AVHRR instrument on the NOAA meteorological satellite, but the coverage is less frequent. However, the spectral coverage is greater in the visible and shortwave infrared. The infrequent overpass time, but far greater spatial resolution of landsat make it an effective complement to the more frequent global coverage of AVHRR with low spatial resolution. Similarly, while the planned EOS sensors, will have frequent global coverage of the Earth's surface, none, including MODIS, will have the same degree of spatial resolution as Landsat TM. In addition, while MODIS and other EOS instruments' spectral characteristics have been planned to understand particular processes on the Earth's surface, and while EOS is planned to provide a long-term time series of observations, only the Landsat time series of data is currently long enough to study many processes of global change. It is important to note that the EOS instruments, particularly MODIS and any possible high spectral resolution instruments, have been planned with the assumption that the Landsat TM survey style measurements will continue, in order to provide a baseline, well-characterized data set for the state of the Earth's surface, within which the more process-oriented EOS specialized measurements can be made. Because of data rate limitations in EOS, however, Landsat TM (and ETM) will remain the sole source of high spatial resolution data collected for the Earth's surface for the foreseeable future.

Continuing the Landsat type data is a priority in the EOS program. A Landsat follow-on type instrument is planned for the EOS AM-2 satellite. Data continuity is the primary requirement as defined by the Land Remote Sensing Policy Act of 1992, Public Law 102-555. Technologies emerging from the Small Satellite Technology Initiative, "Lewis" and "Clark," and the New Millennium Programs will be infused into a Landsat advanced technology instrument for the EOS program, though neither Lewis nor Clark could be considered "replacements" for the coverage and capability of Landsat.

Practical Applications

QUESTION 15. If the MTPE program has had any failing, perhaps it is in not communicating how the satellite data will enhance the lives of the average taxpayer. In the past, most of the discussion regarding MTPE focused on studying whether the Earth is warming and not the practical applications of the data.

a. Would you share with the Subcommittee some of the main practical applications of the satellite data, particularly those of relevance to farmers, ranchers and university researchers?

b. Looking into the future of remote sensing data, what new agricultural applications are likely to be developed? What advantages will satellite analysis of farmland have over ground observations and measurements?

Answer 15. In addition to the long-term science and research uses of satellite data for studying Earth's climate, both MTPE and NASA's Office of Space Access and

Technology have worked to apply satellite remote sensing to practical uses. In a recent survey NASA performed of the uses of satellite remote sensing at all levels of government, the following applications were defined:

1 - Economic Development
2 - Urban/Regional Planning
3 - Mapping/Charting/Geodesy
4 - Land Use/Land Cover Analysis (i.e. wetlands, forest,urban)
5 - Agriculture
6 - Forestry
7 - Rangeland
8 - Emergency Management
9 - Transportation (i.e. corridor planning, routing)
10 - Exploration/Extractive (i.e. mining, oil exploration)
11 - Weather/Climate
12 - Air Quality Monitoring
13 - Water Quality Monitoring
14 - Water Resources (i.e. snow cover, river flows)
15 - Fisheries (i.e. biological production, water temp)
16 - Marine (i.e. physical oceans, wave & current action)
17 - Recreation
18 - Intelligence

Enclosed are charts for three types of instruments which will be launched in 1998, with significant potential for commercial applications. The charts illustrate the variety of science products targeted for marketable uses. The numbers across the top relate to science data products produced by NASA and the applications on the side show the products which can be produced by the commercial sector that are derived from the related science product.

In addition, NASA is pursuing the development of remote sensing techniques for agricultural applications. One notable project is in partnership with the University of Kansas: Landsat imagery is classifying vegetation with enough detail to identify the specific crop types and provide accurate yield estimates. Landsat data are also being used to identify center-pivot irrigated lands, which is an important input to the estimates of aquifer usage rate.

"Precision agriculture" will soon be possible through the use of multi- and hyperspectral remote sensing, which provides insight into the health of crops, enabling growers to address issues of pest control and fertilization; it can also assist in crop selection and planting decisions. Data from other climatic indicators, such as atmospheric moisture and El Niño, provide improved accuracy in short- and long-term climate prediction which is useful in crop planning.

QUESTION 16. I am aware that South Dakota, Montana, and other Plains States have been working with NASA to make MTPE more relevant to the issues we face in our region. What are your thoughts on the kind of infrastructure that NASA needs to establish in the Plains States region to make the satellite data available, in a user-friendly form, to all segments of our communities?

Answer 16. MTPE's work with the Plains States has been valuable in determining the needs for innovation in data distribution. MTPE initiated an extensive user needs analysis to understand how the Earth Observing System Data and Information System (EOSDIS) can address the mutual objectives of federal agencies, commercial value-added industry, researchers, educators, universities, state and local data users, and the public. The infrastructure of EOSDIS can support full dissemination of data through partnerships between all levels of government, industry, nonprofit organizations and universities to take advantage of the unique capabilities within each sector. The level of government support to user service centers can vary depending on the proportion of support the centers give to long-term R&D, and the extent of MTPE standard products supported. NASA's goal is to provide the best possible product and services to benefit the public with the least Federal investment.

In addition to the data dissemination activity, EOSDIS, working in partnership with user service centers, will assist in transitioning MTPE science products to applications/information products through validating applications in pilot test projects jointly with user organizations and their commercial partners. This includes working with software vendors, remote sensing value-added firms and geographic information systems companies to transfer algorithms and government produced processing software/mandated standards for inclusion in commercial products.

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QUESTIONS ASKED BY SENATOR ROCKEFELLER AND ANSWERS THERETO BY DR. KENNEL

QUESTION 1. Privatization. Much has been said recently about privatizing various NASA activities, including possibly the Earth Observing System's Data and Information System (EOSDIS). But questions have been raised about when robust commercial markets for EOSDIS will actually exist. Although these markets are expected to develop over time, the EOSDIS system is still under development and currently focused on collecting data for basic scientific research. For these reasons, some observers believe that privatization at this juncture is premature and, as in the case of Landsat in the early 1980's, not yet ready to become self-supporting in the commercial marketplace. What is your view on privatization? Please tell the committee in detail how privatization can be achieved and over what period of time.

Answer 1. Mission to Planet Earth is first and foremost a science program—the practical applications naturally evolve from the science. Though there is great potential for a value-added applications industry to develop in the future, as of now that industry is still in its infancy. We cannot expect the private sector to invest in pure science, which will not provide them with a short term return on their investment. Our ability to privatize elements of the program would depend upon the ability of external entities to meet EOSDIS requirements, particularly the integration and availability of data.

We are in the process of examining the question of privatization as part of the NASA instituted EOS studies which are in process now. Given the current pace of EOSDIS development, the need to provide timely support to the launch schedules for the initial EOS flight components, and the shifts in the user community anticipated as the data products actually become useful, addressing the issue of privatization before the year 2000 would likely be premature based on our current understanding and on existing and projected market conditions. If NASA were to privatize EOSDIS in the post-2000 time frame, the government would have to insist that the data be preserved indefinitely for future use, the products associated with the instruments must continue to be produced and distributed, and we would have to carefully re-examine policies which restrict the cost of selling the data and which provide for non-discriminatory access.

QUESTION 2. Scientific value of EOS. Over the years the Earth Observing System (EOS) has seen $10 billion cut from its original design and scientific objectives. These reductions have forced the cancellation of scientific instruments and therefore the collection of certain kinds of data—data originally believed to be important for understanding the Earth and particularly for predicting climate. Now we face proposals for even deeper cuts. Please describe the value of the instruments that remain scheduled to fly on EOS satellites, and what will be lost if additional instruments are cancelled?

Answer 2. The EOS-AM-1 observations will address key issues in atmospheric, land, and ocean sciences. The EOS-AM instruments will provide critical data on clouds and radiation fields. These observations, when combined with the equivalent data from EOS-PM, will provide insights into the role of clouds in the physical climate system. The EOS-AM-1 and Landsat measurements will address key issues in land atmospheric, and ocean sciences. Climate processes are the focus of the EOS-PM-1 measurements, though other missions will also make important contributions. Atmospheric chemistry studies will include a number of measurements, including those from instruments on the EOS Chemistry spacecraft as well as SOLSTICE, SAGE, and MOPPITT. Ocean processes, which play a central role in the climate system, will be the focus of measurements both by EOS and other instruments and spacecraft. These measurements, and those made by other agencies and nations, are new in their comprehensiveness, precision, and volume, and ought to advance our scientific understanding significantly.

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As with all EOS measurements, they provide an essential puzzle piece in our efforts to understand changes in the climate on a global scale. The follow-on EOS instruments will focus on how the land, water, atmosphere, and life interact with one another. This approach, called Earth system science—blends together fields like meteorology, oceanography, biology, and atmospheric science. Each EOS satellite will

provide science information on distinct interactions of the land, atmosphere, water and life that will ultimately touch different segments of society—the global understanding will yield local and regional benefits. A sampling of those we can predict with confidence includes.

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This research provides the knowledge necessary to understand the dynamics of our planet. As with all scientific endeavors, Mission to Planet Earth will likely provide some surprising results which will lead to a more advanced knowledge of our world.

We are at a turning point at MTPE. The suggested cuts would dismantle the national approach to US global change research priorities established over the last three Administrations and undercut US leadership in this important area of research. It would destroy the program's basic feature—comprehensiveness—and turn an integrated, global program into a series of disconnected and fundamentally less effective measurements. Worse still, it would condemn American scientists to pursuing an approach to environmental research which is more than a decade out of date.

The cuts would cripple the core of the program—the Earth Observing System (EOS)—the first integrated satellite and research system designed to observe the linkages among all the components of the Earth system—the land, oceans, atmosphere, ice sheets and ecosystems. Understanding these linkages is the critical next step to unlocking the secrets of how the environment works and how it affects us all.

EOS data will help enable us to forecast the climate—a year in advance at first, then progressively longer. The ability to make reliable climate forecasts will have a profound affect on society. Such forecasts are key to major improvements in agricultural and urban planning, water and forest management, investment and capital decisions, and fishing, all of which fundamentally affect US competitiveness, They would enable improvements if our ability to predict and react to natural disasters, like floods and hurricanes, thereby preventing greater loss of life and property. All of these gains would be lost if the proposed cuts to EOS are sustained.

By walking away from the systematic and comprehensive approach for Mission to Planet Earth, the US would also give up its undisputed world leadership in Earth observations, jeopardize technologies which will be critical to the growing commercial remote sensing market, and reduce our ability to influence the global environmental agenda. Significant US investment in environmental science is the key to preserving this impartiality among nations and sustaining US economic Competitiveness in the global marketplace.

NASA is committed to prudent and permanent deficit reduction. Recognizing our fiscal responsibility, NASA has already made enormous reductions in our future budgets. However, further cuts to Mission to Planet Earth—and environmental research in general—seriously jeopardize an investment in the future that will return economic and quality of life benefits far in excess of what we spend today.

QUESTION 3. Potential economic benefits. Mission to Planet Earth and its EOS program will eventually provide a set of scientific data that potentially could aid agricultural officials, city and state land use planners, and public officials who need to deal with floods and other weather emergencies. What do you consider to be the most valuable potential economic benefits of EOS and EOSDIS?

Answer 3. EOS science and measurements will generate significant improvements in our understanding of the Earth's climate and the interactions that govern how it changes. Landsat provides an example of how this data can be transformed from science data to marketable products for state/local governments, farmers, foresters,

educators, and many others. Though we cannot predict with certainty the size and scope of the economic benefits of the EOS program, we believe that the data provides the possibility for a variety of marketable products for a number of users. First, the information from EOS will improve how we plan for the future. Second, EOS will help both to forecast and to respond to natural disasters (like floods, hurricanes, and fires). Third, EOS measurements and technology could spur a new high-tech, commercial remote sensing industry in the U.S. that could contribute significantly to our economy and trade balance.

91-646 (64)

ISBN 0-16-052050-9